PB-223 430

POULTRY MANURE DISPOSAL BY PLOW-FURROW-COVER

Rutgers - The State University

September 1973

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BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA-670/2-73-085	2.	PB 223 430

4. Title and Subtitle

POULTRY MANURE DISPOSAL BY PLOW-FURROW-COVER

5. Report Date
1973-issuing date

6.

7. Author(s)
The College of Agriculture and Environmental Science

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
The College of Agriculture and Environmental Science
Rutgers Univ.--the State University of New Jersey
New Brunswick, New Jersey 08903

10. Project/Task/Work Unit No.

11. Contract/Grant No.
EP-00254

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
National Environmental Research Center
Office of Research & Development
Cincinnati, Ohio 45268

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes

16. Abstracts

This study consisted of 4 years of research conducted to determine the feasibility of the Plow-Furrow-Cover (PFC) method of manure disposal. The purposes of the research included the development of equipment and techniques for the disposal of poultry manure in soil, and measurement of the consequent chemical, physical, and biological changes. Various sections of the report described the development of equipment; effect upon ground water; laboratory decomposition studies and salmonella; and effect on soil water and the soil. Poultry manure was used as the organic waste, and there was no indication of ground water pollution by fecal coliform. The upper limit of poultry manure disposal appeared to be less than 15 tons per acre of dry material because of nutrient contamination in the soil water. The PFC technique utilized the soil media for degradation and the eventual utilization and recycling of organic wastes by plants.

17. Key Words and Document Analysis. 17a. Descriptors

Agricultural machinery, *Deposition, *Organic wastes, Soils, Fertilizers, *Wastes, *Waste disposal, *Pollution, Slurries, Poultry, Water pollution, Soil water, Contamination, Percolation, Equipment, Decomposition, Ground water, Salmonella, Test facilities, Recycling

17b. Identifiers/Open-Ended Terms

*Plow-Furrow-Cover technique, *Poultry manure, Solid waste disposal, Resource recovery, Fecal coliform, Suction lysimeters, Technicon Auto-Analyzer

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US Department of Commerce
Springfield, VA. 22151

17c. COSATI Field/Group 13-B, 2-A, 7-C

18. Availability Statement Release to public	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 203
	20. Security Class (This Page UNCLASSIFIED	22. Price $5.50

EPA-670/2-73-085
September 1973

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By

The College of Agriculture and Environmental Science
Rutgers University--The State University of New Jersey
New Brunswick, New Jersey 08903

Grant No. EP-00254
Program Element No. 1D2063

Project Officer

Harry Stierli
Solid Waste Research Laboratory
National Environmental Research Center
Cincinnati, Ohio 45268

Prepared for
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

In an attempt to solve the problems involved in solid waste disposal, this study, employing poultry manure as organic waste, investigated the Plow-Furrow-Cover method of manure disposal.

A. W. Breidenbach, Ph.D
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

The Plow-Furrow-Cover (PFC) Technique of depositing manures and other organic wastes in the soil has been developed at the College of Agriculture and Environmental Science, Rutgers University - The State University of New Jersey. This method of waste disposal consists of placing a slurry or semisolid waste in a 6-to-8-inch deep plowed furrow. A plow immediately covers the waste and opens the next furrow. With favorable conditions, up to 2 inches of slurry can be completely covered. This is equal to approximately 50 tons of dry manure, or about 200 tons of wet poultry manure (25 percent solids), per acre.

In a U.S. Environmental Protection Agency (U.S. Public Health Service) supported study of more than 3 years' duration, using poultry manure as the organic waste, there was no indication of ground water pollution by fecal coliform. However, the upper limit of poultry manure disposal in soil appears to be less than 15 tons per acre of dry material because of nutrient contamination in the soil water. The upper limits of other waste application rates and the corresponding potential nutrient contamination of percolation water was not determined.

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INVESTIGATORS

Principal Investigators
  December 1, 1966 - January 29, 1969
    Billy Ray Wilson, Chairman, Bureau of Conservation and Environmental Science
  January 30, 1969 - March 31, 1970
    Harry E. Besley, Research Professor of Agricultural Engineering and Assistant to the Director, New Jersey Agricultural Experiment Station

Co-Principal Investigators
  Melvin S. Finstein - Associate Professor, Environmental Sciences Department
  Emil J. Genetelli - Associate Professor, Environmental Sciences Department
  Charles H. Reed - Professor, Biological and Agricultural Engineering Department
  Joseph E. Steckel - Professor, Soils and Crops Department

Assistant Investigators
  Jose F. Badillo - Research Assistant
  Jorge H. Berkowitz - Research Assistant
  Thomas J. Concannon - Research Assistant
  George Dozsa - Laboratory Technician
  Harold H. Henderson - Research Assistant
  Daniel J. Kraft - Research Assistant
  John H. Martin, Jr. - Research Assistant
  Barbara M. Metzger - Research Assistant
  George I. Nzewi - Research Assistant
  Nicholas E. J. Rogers - Research Associate
  Gyula Julius Szamel - Research Associate
  Philip R. Warman - Research Assistant

Summary of Research

Four years of research at the College of Agriculture and Environmental Science, Rutgers University, have been conducted to determine the feasibility of the Plow-Furrow-Cover (PFC) method of manure disposal.

This technique was developed by Charles H. Reed, professor of agricultural engineering at the College and one of the investigators in this study. The purposes of research done under this U.S. Public Health Service grant included the development of equipment and techniques for the disposal of poultry manure in soil and measurement of the consequent chemical, physical, and biological changes.

Three departments of the College were involved: agricultural engineering, environmental sciences, and soils and crops. The work itself was divided between field and laboratory.

The PFC method of waste disposal consists of depositing a slurry or a semi-solid waste in a 6-to-8-inch-deep plowed furrow. A plow immediately covers the waste and opens the next furrow. With a properly adjusted plow and the soil in good, plowable condition, up to 2 inches of slurry can be completely covered. This is equal to approximately 50 tons of dry manure or, in the case of poultry manure (25 percent solids), about 200 tons of wet manure per acre.

The test plots were located on a Freehold loamy soil at the Rutgers University Soils and Crops Research Center, Adelphia, N.J. The clay content of the B horizon varied from 15 to 33 percent. The general plan of the experiment was to take soil and soil water samples, the latter by means of suction lysimeters, to a depth of 4 feet periodically after disposal of 0, 15, 30, and 45 tons of poultry manure (dry basis). These samples were then analyzed chemically with the Technicon AutoAnalyzer to determine any change in the nutrient content. The date of the first application was June 6, 1968.

In the soil depth of 4 feet, the chemicals found dissolved in the soil water increased with additional manure applications. The amounts of potassium, magnesium, sodium, chloride, and sulfate in the soil water peaked in 83 days during which 16 inches of rain fell. The peak nitrate-nitrogen concentration in the soil water was 700 parts per million at the 3 foot depth 391 days (with 54 inches of rain) after disposal. On the same date the concentrations at the 1, 2, and 4 foot depths were 200 ppm, 500 ppm, and 450 ppm, respectively. Ammonium-nitrogen peaked at 300 parts per million at the 1-foot depth 57 days after disposal and at 428 days decreased to a very low concentration. Dissolved calcium was high (up to 1,000 ppm) at all sampling dates.

The analyses of the soil samples showed that each of the elements studied had migrated down in the soil from the 7-inch placement. In the 18-month sampling period the soil had retained one-half of the added potassium, one-third the nitrogen, one-third of the chloride, a very small amount of the calcium, and most of the added phosphorus. Late fall disposal of the manure prolonged the supply of soil ammonium very late into the next season.

By 131 days after disposal, the nitrate-nitrogen content of the soil water was 900, 120, 50, and 5 parts per million at the soil depths of 1, 2, 3, and 4 feet respectively. It had been thought that nitrate would have leached to the 4-foot depth by the 19 inches of rain. Since this did not occur, the experimental plan was modified to maintain the disposal plots as barren of crop in 1969 as they had been in 1968. Thus the interaction of crop root removal or interception of soluble forms of nitrogen did not confound the nitrogen mobility measurements.

Disposal of poultry manure in the soil increased the crop nutrient content of the soil water and of the soil. There should be real concern over nutrient contamination of water percolating through soil into which as much as 15 tons per acre of poultry manure (dry basis) have been disposed. This percolation may be the recharge water for a public supply.

A concurrent independent investigation of the pollution potential of field plot percolation waters, as found in samples collected from zero-tension lysimeters at a depth of 4 feet, showed some slight changes in total organic carbon, NO_3, SO_4, and Cl concentrations. However, it should be noted that the results were highly variable.

The lack of positive fecal coliform tests combined with relatively low levels of contaminants in the samples would tend to indicate that no significant pollution in ground water from the application of up to 45 tons per acre of poultry manure (dry basis) occurred during the testing period. Levels of nitrates (NO_3) and total organic carbon did increase, but no significant difference could be found between control and treated plots. The results indicated a general increase in contaminant levels in all waters collected from zero-tension lysimeters.

The attached line drawing illustrates the farm equipment developed up to this time for the disposal of animal wastes by PFC. The components are a standard tractor and single bottom moldboard plow, available commercially; the trailer chassis with offset gooseneck tongue, not available commercially; and the tank, many of which are commercially available and could be adapted for this purpose.

Two additional studies examined the decomposition of poultry manure in soil and evaluated the potential of Salmonella contamination. By these tests decomposition was most rapid at 10:1 to 10:2 (soil:excreta) than at higher loadings of up to 10:10. The 10:1 ratio corresponds to approximately 100 tons of excreta per acre (dry basis), which is more than double the maximum loading used in these studies. Temperature was found less important than the ratio of soil to manure, and soil texture was an insignificant factor.

Chicken manure was found to be a source of Salmonella and thus a potential contaminant of the environment with pathogenic microorganisms. Storage of moist manure for approximately 3 weeks at 20 degrees Centigrade generally assured the death of Salmonella.

The PFC technique utilizes the soil media for degradation and the eventual utilization and recycling of organic wastes by plants. With a closed system such as this, there are no odors and no opportunity for flies to breed or feed. Unless there is massive soil erosion, there is no surface runoff of pollutants. There is no indication of ground water pollution by fecal coliform. The upper limit of poultry manure disposal in soil appears to be less than 15 tons per acre of dry material because of nutrient contamination in the soil water. The upper limits of other waste application rates and the corresponding potential nutrient contamination of percolation water have not been determined.

Poultry Manure Disposal by Plow-Furrow-Cover: Development of Equipment

Prepared by: Charles H. Reed

The agricultural engineering phase of this report relates to: the development of farm equipment components for Plow-Furrow-Cover (PFC) and Sub-Sod-Injection (SSI); the evaluation of some performance characteristics of these components; and the selection of the best components for disposal of poultry manure slurries by this technique.

Equipment has been developed to incorporate biodegradable waste slurries with up to 25 percent solids into the aerobic horizon of the soil where they are degraded and utilized by soil organisms and plants. The incorporation of wastes directly into the soil is superior to surface spreading because there are no odors, no opportunity for flies or other pests to breed or feed, and no runoff or surface erosion of wastes.

The Plow-Furrow-Cover (PFC) technique consists of depositing a slurry or a semi-solid waste in a 6-to-8-inch deep plowed furrow. Immediately after deposition, a 16-inch single-bottom moldboard plow covers the waste and opens the next furrow in the same operation. With properly adjusted equipment, from 1½ to 2 inches of slurry can be completely covered. This is approximately 170 to 225 tons of slurry per acre. A well-formed furrow 16 inches wide, 7 to 8 inches deep, and 400 feet long with 1½ inches of slurry contains 500 gallons or approximately 2 tons. PFC leaves the soil well plowed and ready for disking and seeding. The equipment will operate at 3 mph and unload up to 200 gallons of slurry per minute. The actual rate of application should be governed by the composition of slurry and soil condition (see Figures 1, 2, 3, and 4).

With the Rutgers Sub-Sod-Injector, a band of slurry up to 1½ inches thick and 24 inches wide can be injected from 6 to 8 inches beneath the sod without turning over sod or soil. This injector with its 50-square-inch inlet, connected to the tank with a 6-inch diameter hose, will inject up to 400 gallons of slurry per minute. It has a standard ASAE Category 2, three-point hitch with a spring-trip release for passing over subsurface objects. It is comparable to a two-bottom plow in weight and durability.

Factors to consider when selecting equipment for PFC and SSI are: quantity and physical properties of the waste to be handled; required mixing or agitation; methods of loading and unloading; load-carrying capacity of the soil as related to tank capacity and number and size of tires; management of crops on the disposal site; and distance to transport waste (farm unit or highway-field transport).

With a selection from **six** basic interchangeable components, animal manure slurries with solid content ranging up to 25 percent (wet basis) may be disposed of by either PFC or SSI. These components are described as follows:

(1) A standard Category 2 farm tractor with a three-point hitch.

(2) A standard three-point hitch, 16-inch, single bottom moldboard plow with a Category 2 mast.

(3) A Sub-Sod-Injector with a standard three-point hitch and Category 2 mast.

(4) A trailer chassis designed to permit using either component 2 or 3 above, either of which may be mounted on the tractor or component 6.

(5) A tank to be mounted either on component 4 or 6, which will contain a device to mix and unload slurries.

(6) A four-wheel-drive truck chassis with flotation tires. Components 2 or 3 and 5 may be mounted on this chassis and result in a self-propelled highway field transport for mixing and disposal of wastes by PFC and SSI.

In table I are listed the characteristics of the components of the tank trailer units, which have been constructed and/or tested since the initiation of this USPHS Project #EC00254-03 in September 1966. The names of the units are arranged in the chronological order of development and testing. As indicated in the commentary to follow, the "yes" answers are preferable to "no" except for the offset tongue. The relative merits of these components will be discussed in the text to follow: (con't. on page 7)

Table 1. Characteristics and Performance of the Components of Tank and Trailer Units for Plow-Furrow-Cover and Sub-Sod-Injection.

	Agway('64)	Clay('66)	Rutgers('67)	Laurel('68)	Rutgers('70)
Std Plow & Hitch	No	No	No	Yes	Yes
Location	Trlr	Trlr	Trlr	Trctr	Trctr
Penetration	Poor	Poor	Poor	Excl	Excl
Trailer Tongues					
Straight	-	Yes	-	-	-
Straight-Offset	Yes	No	Yes	Yes	-
Gooseneck	-	-	-	-	Yes
Use of PTO	No	Yes	No	No	No
Wheels in furrow	Yes	No	Yes	Yes	Yes
Controls	Fair	Fair	Fair	Good	Excl
Agitation	Excl	Fair	Poor	None	Excl

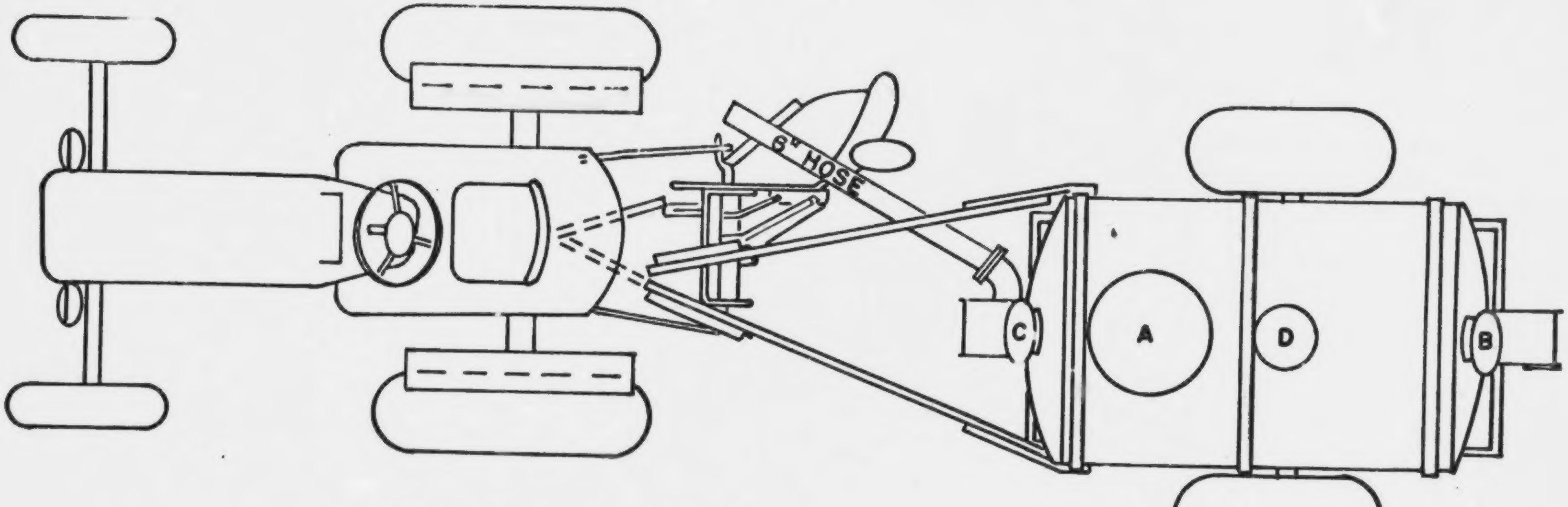


FIGURE-1A TOP VIEW

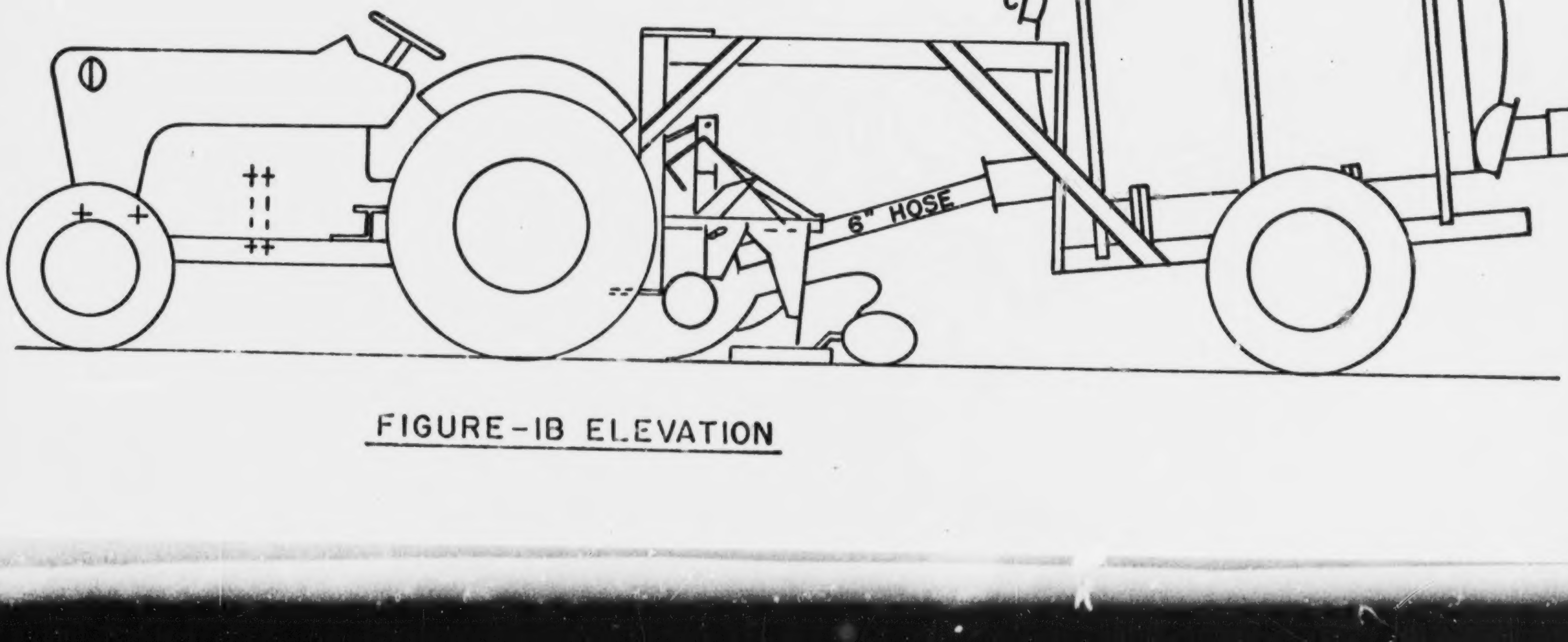


FIGURE-1B ELEVATION

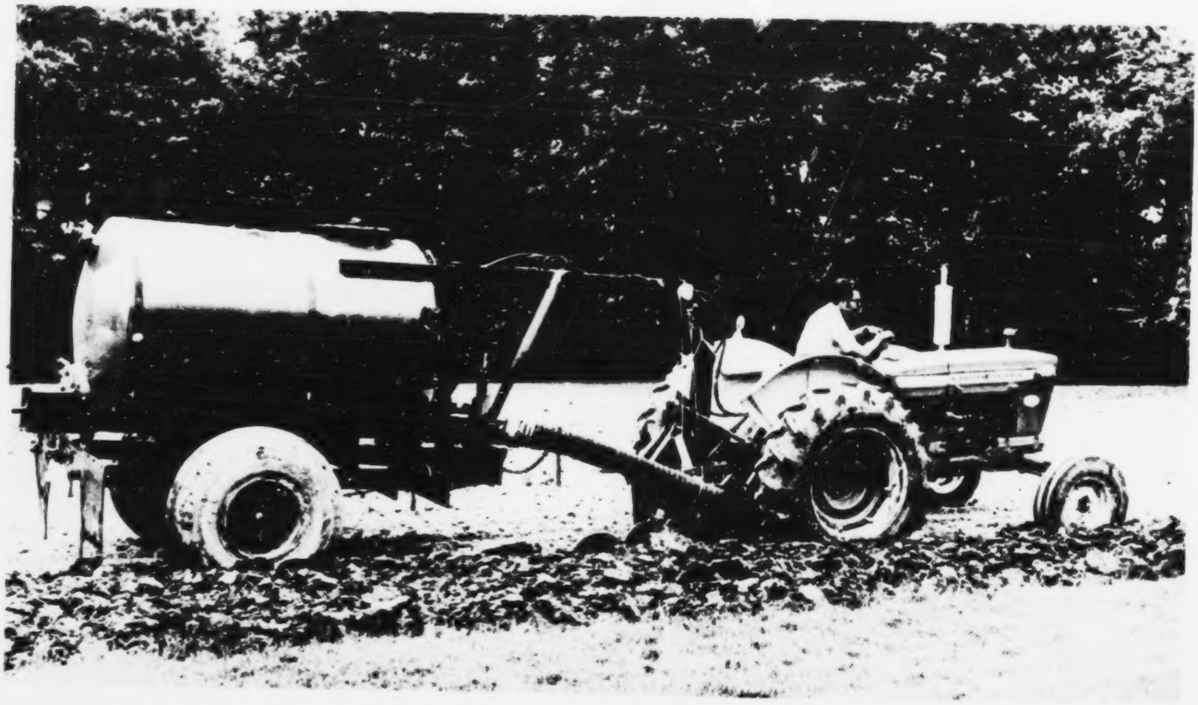


Figure 2. Farm equipment for Plow-Furrow-Cover for the disposal of semi-solid wastes. The gooseneck tongue permits easy maneuverability of tractor on which is mounted a plow or sub-sod injector.

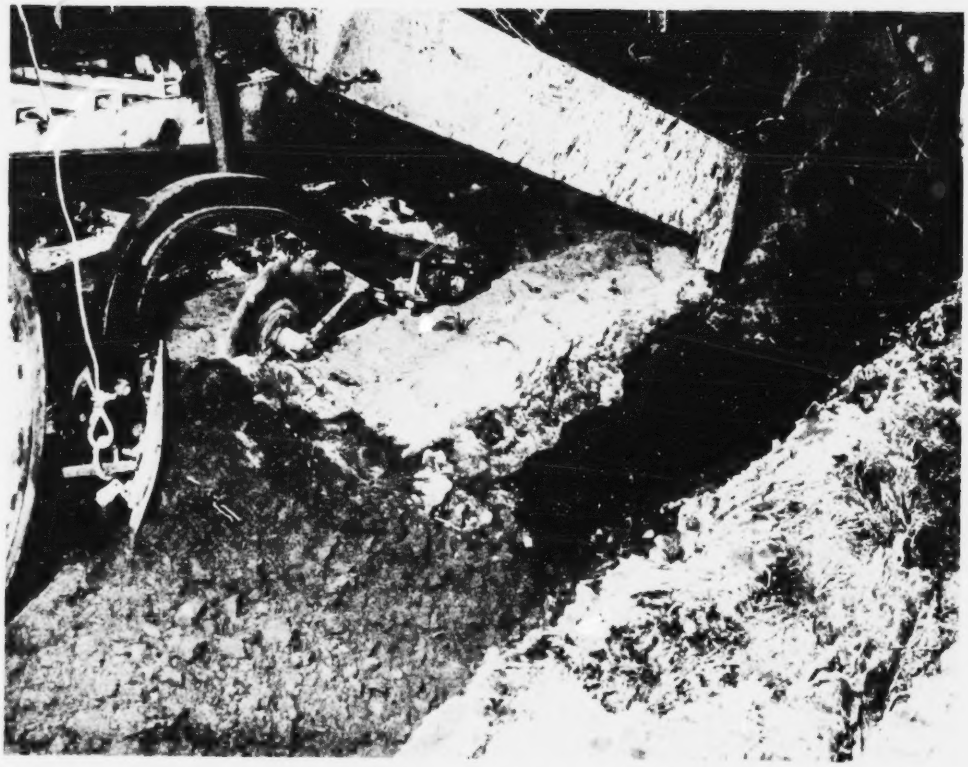


Figure 3. Manure is deposited in the furrow at the rear of the tractor wheel. The plow covers it forming the next furrow.

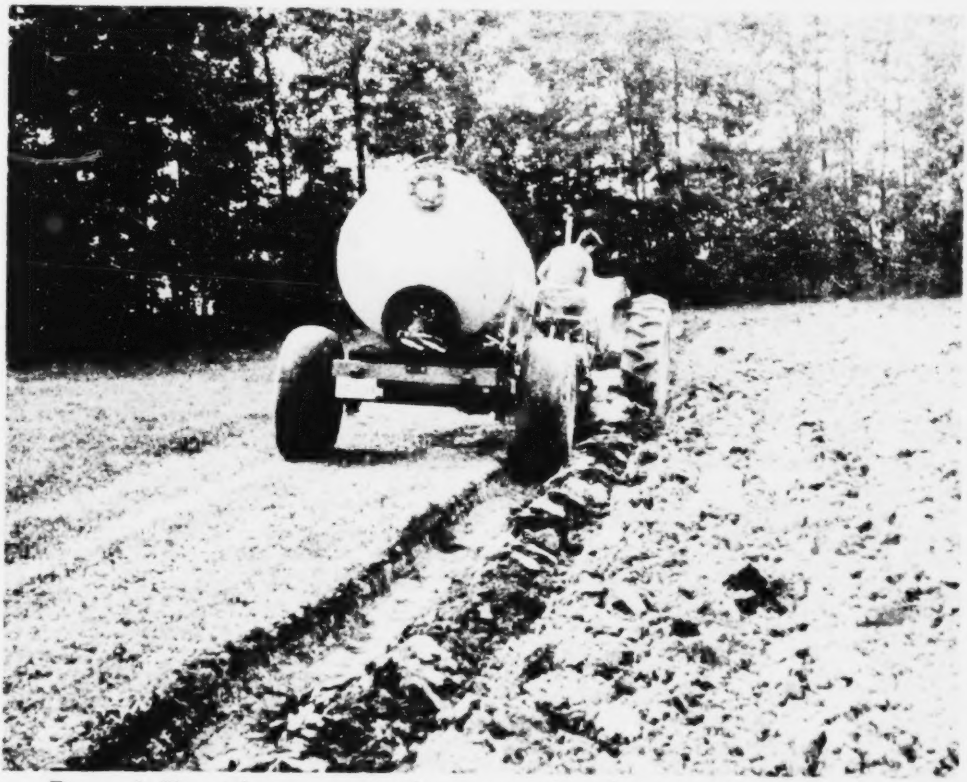


Figure 4. The right tractor wheel runs in a clean furrow, and an offset trailer tongue permits the right trailer wheel to run in the newly plowed furrow.

The Rutgers ('70) represents the best selection of components envisioned, developed, and tested to December 1970. All of the components were demonstrated on one or more of the previous units. The general configuration is shown in Figures 1A and 1B and the completed equipment is illustrated in Figure 2. A prototype of the gooseneck tongue was demonstrated with the remodeled Clay ('66). The tank and running gear is that of Rutgers ('67), with the gooseneck adapted.

The Tractor

The farm tractor used in this development was a Ford 4000, Category 2, Class D. Rear wheels were spaced 28 and ½ inches from the center line of tractor to inside side wall of tire, front wheels were spaced one-inch wider. Sidedraft was not appreciable in good plowing with this size tractor.

Trailer Tongues

Three types of tongues have been used on the trailer chassis: straight, offset straight, and offset gooseneck. The following procedure has given best performance to date with the Plow-Furrow-Cover method: right rear tractor wheel runs in a clean furrow; waste is deposited in the furrow at the rear of the tractor wheel; plow covers the waste; and the right rear trailer wheel runs in the clean, new furrow. This procedure requires that the trailer wheels run 16 inches to the left of the rear tractor wheels (see Figures 3 and 4).

The tongue or trailer axle should be adjustable to correct the offset for each tractor and plow combination. The change from the required offset for PFC to tracking or no offset for SSI and highway transport is accomplished by temporarily disconnecting the upper link of the three-point hitch and swinging the tractor drawbar and tongue to the right. With a permanently attached straight tongue (Clay '66), this adjustment is not necessary. However, with all the tractor wheels on the land and with wet or hard plowing conditions, sidedraft pulls the front tractor wheels into the furrow. An offset tongue counteracts some of the sidedraft resulting from the plow mounting off the centerline of the tractor.

The Gooseneck Tongue

The gooseneck tongue, as shown by Figures 1A, 1B and 2 will permit the use of either a standard three-point-hitch plow with only slight modification, or the Sub-Sod-Injector, either of which is mounted on the three-point hitch of the tractor. They may be easily controlled with the usual hydraulic equipment on the tractor.

Trailer Axles

Single-axle trailers with single wheels have been used up to this time in the development. However, if loads on wet soil are larger than 1,000 gallons, other types of chassis should be considered. With the single-axle trailer, about 1,500 lbs. of the gross load may be safely carried on a Class D tractor drawbar. Comments on three other types of trailers follow:

A two-axle tandem would have nearly the same maneuverability as a single-axle trailer. There would be less load on the tractor drawbar resulting in a lighter weight and a less costly gooseneck tongue. A two-axle wagon trailer with automotive type tie-rod front wheel linkage has poor maneuverability. However, the gooseneck tongue could be lightweight and only slightly more expensive than a conventional straight tongue for a conventional two-wheel trailer. Linkage for steering between the gooseneck to the tie-rod would not be complicated.

A trailer chassis with two-caster wheels and one axle (Coby's "New Caster Gear") might have all the advantages of three previous schemes. Also, the gooseneck tongue might be attached directly to the tank, thus further reducing the cost of the tongue. The adjustment for the tongue offset could be made at the connection of the tank to the trailer chassis.

The Plow

Two methods of moldboard plow hitches and locations were used in this development. One was a standard three-point-hitch plow integrally mounted on the regular three-point linkage of a standard tractor as on the Laurel ('68) and Rutgers ('70). The other method was a specially assembled plow, mounted on the side of the trailer; i.e., the Agway ('64), Clay ('66), and Rutgers ('67). The integrally mounted plow on the tractor was very definitely superior in regard to ease of control, maintenance, durability, economy, and normal penetration. The only advantage of the trailer-mounted plow was that the PTO of the tractor could be used for power for the auger and vacuum-pressure pump. For a minimum of sidedraft on the front tractor wheels, a furrow wheel should be used instead of either a long landside or laterally restraining the linkage on the tractor.

The plow on the Rutgers ('70) was assembled from components of a Massey-Ferguson MF 82 Mounted, three-bottom, 16-inch plow. The first bottom with coulter and furrow wheel was moved to the right on the lower linkage adjustment crank (cross bar) in order to operate properly when the rear tractor wheels are adjusted to 57 inches between tire side wall to side wall. The upper link was parallel to the direction of travel.

The Tanks

Each of the tanks listed in Table I had a capacity of approximately 800 gallons and were vacuum-pressure tanks, except the Agway ('64). The primary reason for a vacuum-pressure tank is for loading and possibly unloading. If the slurry is of uniform consistency and not more than 12 to 15 percent solids wet basis, it may be loaded by vacuum. Slurries with up to 20 percent solids have been loaded with some difficulty, but it is not practical. There was no difficulty in unloading slurries of uniform consistency with 20 percent solids by gravity through a 6-inch diameter flexible hose, without an auger. Other methods of loading, i.e, pumps, bucket elevators, or conveyors, might be more satisfactory and economical when compared to the added cost of a vacuum tank. With an open type tank, the costs of the pump and power plus hoses and valves must be considered. The Rutgers('70)was not operated as a pressure-vacuum tank.

A tank to be loaded by vacuum and perhaps unloaded by some pressure should have dished ends and walls of ¼-inch mild steel plate (see Figure 2.). Some of the presently manufactured liquid manure tanks could be used if a front outlet were installed as shown by Figures 1A and 1B.

Agitation

Four types of agitation were used: (1) air compressed by the vacuum-pressure pump and blown through a manifold consisting of a 1½-inch diameter pipe with six 3/4-inch holes 9 inches on centers; (2) a three-blade propeller 12 inches in diameter with a 12-inch pitch operated by a hydraulic motor; (3) a piece of a screw conveyor 6 inches long and 12 inches in diameter operated by the PTO from the tractor (Clay '66); and (4) the most satisfactory was a 6-inch diameter screw conveyor the full length of the Agway ('64) tank (10 ft.), operated at speeds up to 560 rpm, and one in the Rutgers ('70) operated at less than 1;5 rpm (as recommended by the manufacturer). The auger in the Rutgers ('70) is a Link Belt 6H308 conveyor screw. The end troughs are No. 97-CM angle flanged with flush-end discharge spout 117-AP.

The auger may be optional equipment. If optional, it should be installed on plates which are bolted and sealed to the ends of the tank and replaceable with cover plates with connections for outlet hose.

Openings on Vacuum Tank

Opening A (see Figure 1B) is a standard quick-actuating cover for inspection or loading with pump, elevator, or elevated tank. The cover was installed on an 18-inch tank flange.

Opening B (Figure 1B) is a standard 6-inch bolted companion flange with a threaded close-up welded into the tank and is the inlet for vacuum loading. If located as high as possible in the upper part of the tank, the load is not siphoned or blown back into a storage tank if vacuum ceases or stoppage in the suction hose occurs.

Openings C and D are similar to B with 1/8-inch thick covers bolted onto the flange. The pressure gauge vacuum hose, and automatic shut-off were installed in cover D. The shut-off prevents the entrance of waste into the vacuum line and pump. A sight gauge was in cover C. Openings C and B shoudl be as high as possible on the ends of the tank.

Power for Auger and Vacuum Pressure Pump

An efficient method of providing the power for the auger and vacuum-pressure pump has not been determined. With the plow or injector mounted on the three-point hitch of the tractor, a PTO drive shaft cannot be used to drive the auger.

A 5 to 7 hp engine or hydraulic motor mounted on top of either end of the auger housing would provide sufficient power for operating the auger. However, this might not provide sufficient power for the best operation of the vacuum-pressure pump. The latter could be mounted on the rear-axle housing of the tractor and belted to the PTO of the tractor. The auger in the Rutgers ('70) was turned by a hydraulic motor developing approximately 2 hp.

If a vacuum-pressure pump is used for loading, other accessories are a moisture trap and moisture relief valve. An easily cleaned sight gage is essential.

The Outlet Valve

The valve at the end of the outlet hose may be attached to the tractor fender or rear axle or to the gooseneck tongue, permitting quick control of valve with a minimum of linkage. The is a low-pressure quick-acting 6-inch valve. Two commercially available valves are manufactured by the DeZurik Corporation, Startell, Minnesota; and the Fab Valve Company of America, P.O. Box 4352, 2100 Alvina Avenue, Portland, Oregon.

A satisfactory valve was fabricated in the agricultural engineering shop of the College of Agriculture and Environmental Science, Rutgers University.

Conclusions

Plow-Furrow-Cover and Sub-Sod-Injection techniques and equipment are feasible and practical for the incorporation of biodegradable wastes in the upper aerobic region of the soil where they are degraded and utilized by plants. They have been used quite extensively for animal wastes. The equipment has been used for septic tank pumpouts (U. of Conn.) and for sewage sludges with up to 9 percent solids. Sewage sludges have more uniform physical properties than animal wastes and consequently are easier to handle.

The equipment has been developed to the extent that it is ready for manufacturers to field test prototypes prior to marketing.

Two major problems with this method of waste disposal are winter storage when the soil is frozen and transportation cost of high moisture content sewage sludge. Also, many farmers are changing management practices from handling high water content manures to semi-solid low-moisture manures. Equipment should be developed to incorporate semi-solid manure and sewage cake into the soil in order to reduce the costs for winter storage and transportation.

Termination Report

EFFECT UPON GROUND WATER

Prepared by

Emil J. Genetelli

Disposal of poultry manure is an acute problem to New Jersey and the United States owing to the great amount produced yearly (300,000 tons in New Jersey and 2 million tons in the United States). Several methods of disposal have been proposed and studied (2,4,6,8,9,10,11,13), four of which utilize the soil as a disposal medium. Lagooning, as recommended by Eby (4), causes an odor and mosquito problem and would also produce eutrophication of surface waters. Sanitary landfilling, as discussed by Black (2), requires only a small land area, but would cause a buildup of manures which would take years to decay and possibly contaminate ground waters. Sub-Sod-Injection, covered by C. H. Reed (10), is not yet fully developed while surface spreading of liquid manure, discussed by Hart (6) and Taiganides (11), causes a fly and odor problem and can result in surface water pollution. The Plow-Furrow-Cover method, as discussed by Reed (10), would not cause fly or odor problems, involves a simple technique, and results in a stabilization of manures in a fairly rapid time.

Poultry manure has been used as fertilizer by farmers for many years for its beneficial residual effects on crop production. Never, however, has the soil been used specifically as a prime disposal medium for so huge and concentrated a loading of organic waste without regard to residual effects.

The purpose of this phase of the project was to obtain some insight into the pollution potential of this method of disposal to the ground water. It was accomplished through an investigation of specific elements in field plot percolation waters.

METHODS AND PROCEDURES

Field Plots and Lysimeters

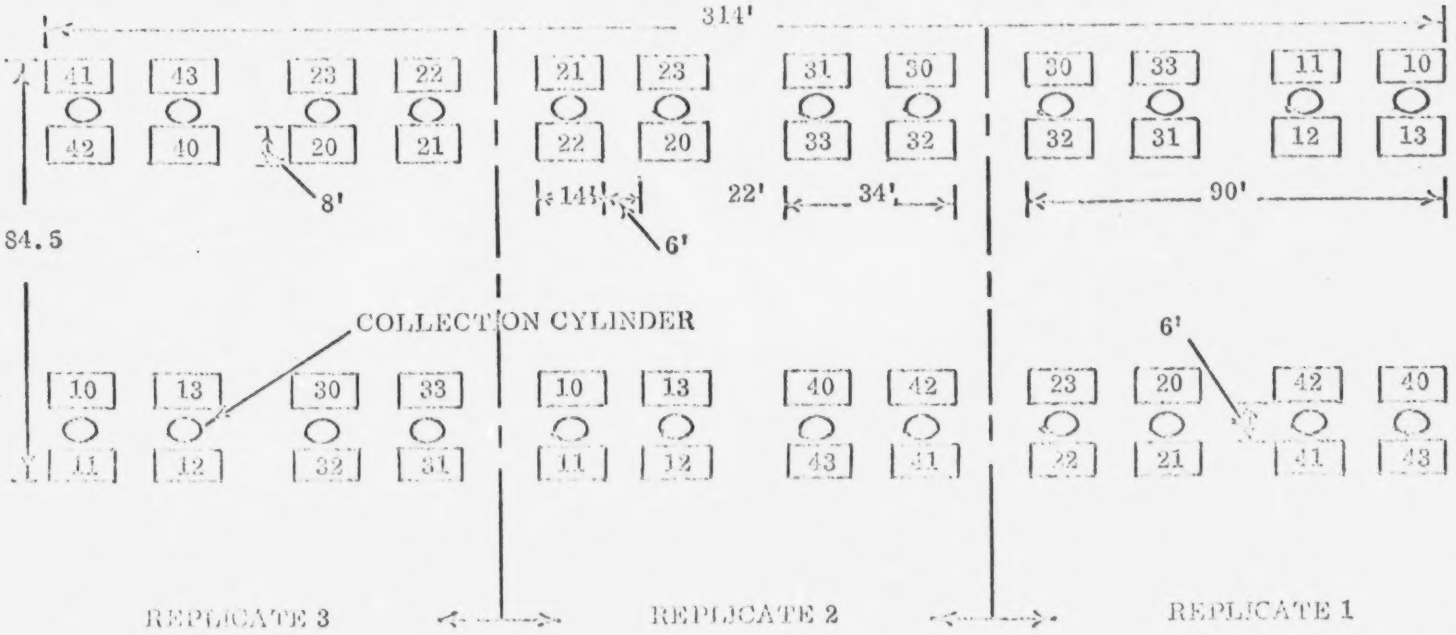
The field procedure followed to determine ground water pollution included three replicates of 16 field plots with four loading rates and four application times (Fig. 1). The loading rates were 0, 15, 30, and 45 tons of dry poultry solids per acre. The application times were June, August, October, and split application with one-half in May and the remainder in August.

In order to determine changes in percolation water quality, porous cup or suction lysimeters and zero-tension lysimeters of the Ebermayer type were used.

The porous cup lysimeters were porous ceramic cups approximately 1½ inches in diameter and 3½ inches long attached to plastic piping of varying lengths. These lysimeters were installed by the Soils and Crops Department in all plots except those receiving the split application. A soil core was made to the desired depth and the lysimeter inserted. Sample was collected by use of a vacuum pump and polyethylene micro-tubing. Each plot contained five porous cup lysimeters at the 1, 1½, 2, 3, and 4-foot levels. These lysimeters, although easy to install, filtered out coliform in laboratory studies, making them useless for any field bacteriological work.

The zero-tension lysimeters (7), as shown in Fig. 2, were of the Ebermayer type. The basic lysimeter was a 2 x 12 inch stainless steel trough drained by two stainless steel pipes or collection tubes, one inside the other. The upper or collecting surface had screening suspended from all sides forming a small stretcher 2 x 12 inches. Under the screening were two bars, side by side, touching the screening along the center line and running into the inner collection tube.

The screen stretcher was packed with glass wool and then with soil. Rubber micro-tubing was attached to the smaller stainless pipe and polyethylene tubing was slipped over the micro-tubing and attached to the larger pipe. A tunnel was dug under the plot to be studied and the lysimeter


314'
41
43
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32
31
12
13
8'
14'
6'
22'
34'
90'
84.5
COLLECTION CYLINDER
6'
10
13
30
33
10
13
40
42
23
20
42
40
11
12
32
31
11
12
43
41
22
21
41
43
REPLICATE 3
REPLICATE 2
REPLICATE 1

CODE EXPLANATION
10

APPLICATION CODE

1 - June
2 - August
3 - October
4 - Split May/August

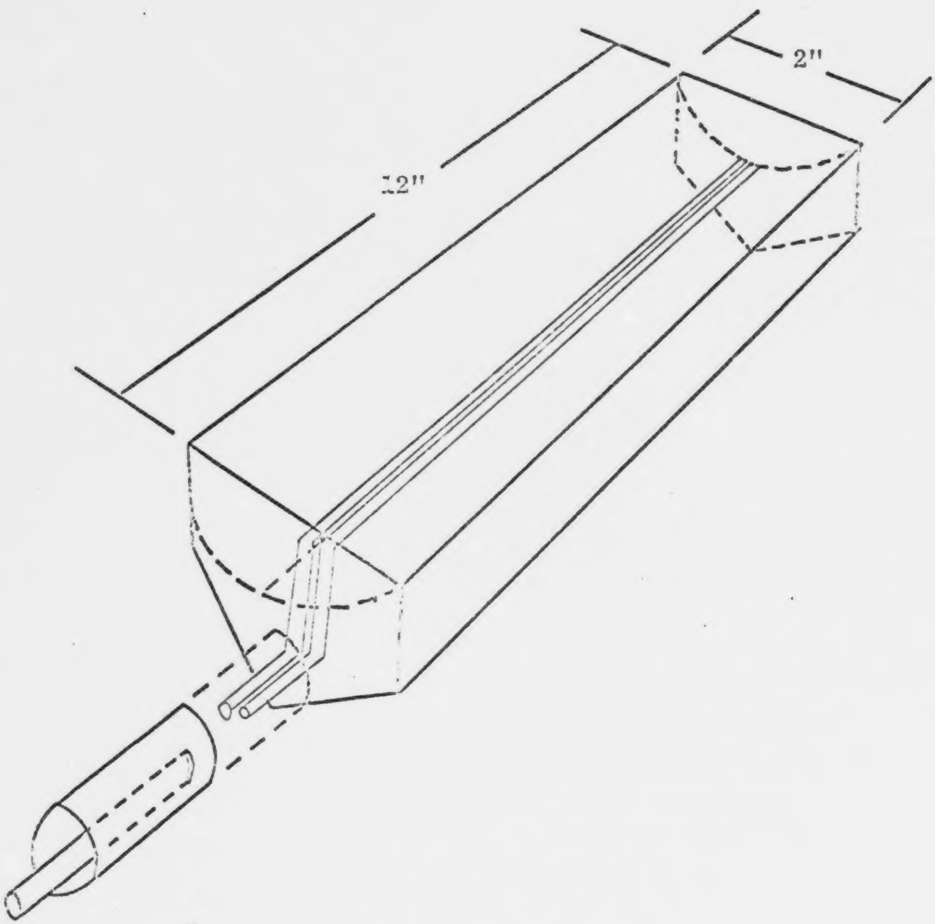
TREATMENT CODE

0 - 0 Tons/Acre
1 - 15 Tons/Acre
2 - 30 Tons/Acre
3 - 45 Tons/Acre

Figure 1.

FIGURE 2

ZERO-TENSION LYSIMETER



inserted with the soil in the top of the lysimeter touching the soil on the top of the tunnel. A wooden wedge was placed under the lysimeter to secure it, and the tunnel was backfilled, insuring that the contact edge between trough and tunnel roof was tamped with damp soil.

The zero-tension lysimeters were placed at the 4-foot level since it was felt that any contamination reaching this level would enter ground water. To install the lysimeters at the 4-foot level, a tractor mounted backhoe was used to dig a hole between plots. The tunnels were dug by hand and the lysimeters installed. A collection cylinder resembling a steel manhole was fashioned out of two 55-gallon drums welded together. The collection tubes from the lysimeters were inserted into holes drilled in the collection cylinder. The hole was backfilled using a light bulldozer. The collection tubes in the cylinder were then inserted into 1-gallon glass bottles. The collection cylinders were covered with steel lids.

The lysimeters collected the water moving down through the soil. The water passed through the glass wool and onto the screening. From there it moved down and into the microtubing eventually reaching the collection bottle.*

Samples were collected weekly and the bottles cleaned after each sampling. Twenty-four lysimeters were installed in November, 1967; however, no sample was obtained until early April, 1968. This was probably due to the existence of a temporary interface between the soil in the lysimeter and the soil above, and also the freezing and thawing of the soil during the winter. In May of 1968, 36 more lysimeters were installed. Following the installation, there was over 4 inches of rain in less than a week's time. This great amount of rainfall caused flooding in the drums due to a rise in the ground water level. The drums were pumped out and sample bottles replaced. The remaining 36 lysimeters were installed in June, 1968. Figure 3 shows a cross-section of the two adjoining plots, the collection cylinder and lysimeters.

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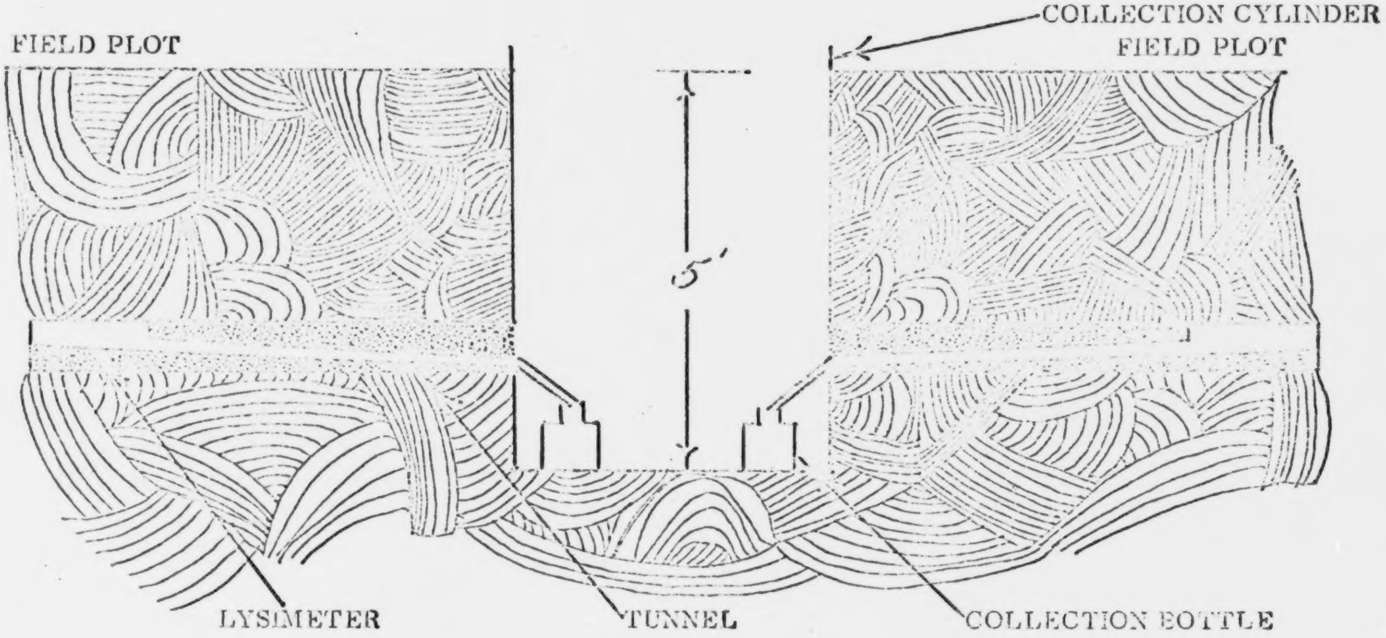
*This report deals only with the data generated from the zero-tension lysimeters.


FIELD PLOT
COLLECTION CYLINDER
FIELD PLOT
5'
LYSIMETER
TUNNEL
COLLECTION BOTTLE

FIELD PLOT CROSS SECTION

Figure 3.

Analyses

The Soils and Crops Department performed the analyses to determine the concentrations in the sample of calcium, magnesium, sodium, potassium, sulfates, chlorides, phosphates, ammonium, nitrate, and nitrite nitrogen. These analyses were done using the Technicon Auto-Analyzer.

The total organic carbon analysis (TOC) which was used as a measure of the organic pollution present in water, was performed using the Beckman Carbonaceous Analyzer. Carbon dioxide and carbonate were removed by acidification of the sample with a normal solution of hydrochloric acid and bubbling the sample with nitrogen gas for 3 minutes. The prepared sample (5) was injected into the carbonaceous analyzer which is a combustion infrared analyzer. The sample passed through the combustion tube which was packed with asbestos impregnated with cobalt nitrate. At this point the sample changed to the gaseous state with any organic carbon present becoming carbon dioxide. The amount of carbon dioxide thus formed was analyzed by an infrared analyzer and was read out on a belt-driven chart as organic carbon in milligrams per liter.

Samples found high in organic carbon were tested for bacteriological contamination. The fecal coliform test was chosen because of its specificity. The chance of contamination by aerobacter aerogenes and other organisms giving positive results in the most probable number coliform test was great at the field location since these organisms are normally found in decaying plant material. Further, the method of sample collection could have caused contamination by such organisms since the bottles were removed from the collection drums and any sample present poured into test tubes in the open air. Since the fecal coliform test is specific for only those coliform present in fecal matter, it eliminates the possibility of positive test results from other organisms.

The fecal coliform test is an elevated temperature test which is a direct count method for determining fecal coliform present in a water sample. The test was run using Difco mFC broth base. Two milliliters of the broth was applied to a sterile millipore absorbent pad in a plastic petri dish with a tight fitting cover. The water sample was filtered through the millipore membrane. The membrane was placed on top of the absorbent pad in a petri dish which was then incubated submerged in a 44.5^{o}C. water bath for 24 hours.

FIELD PLOT CONTAMINANT CONCENTRATION

Results

In order to simplify the data for comparison, a modified system for handling it was utilized. Contaminant concentrations for weekly samples were segregated by application time and treatment and an average taken for each month. These average values were used for statistical analyses.

However, even a cursory review of this data will reveal extreme variability in the results. It was hoped that the information obtained from the zero-tension lysimeter study in this ground water phase would complement the data obtained from the suction cup lysimeter study in the soil water phase and provide valuable information about the mineral and carbon content of percolation water just before it entered the ground water supply. Unfortunately, the experiment was subjected to unanticipated and uncontrolled variables. For example, zero-tension lysimeters did not receive equal amounts of water even when placed side by side under a plot. In fact, in certain instances, one lysimeter would obtain a sample while another lysimeter would not receive any sample whatever. In major instances throughout the study program, flooding occurred in the sample collection barrels containing the zero-tension lysimeter collection bottles. Investigations during the course of the study revealed that bank storage hydrological effects were being felt due to the close proximity of a pond to the plots. Dye studies indicated water movement in all directions laterally as well as vertically. Regression analysis was performed on the data. However, low correlations of .1 or less were found, indicating no trends in the data. Analyses of variance were also performed on the data, and these analyses showed no significant difference between any of the treatments and the control. This, however, does not mean to say that the possibility of pollution did not exist. The data were so variable that very large differences in values would have had to occur in order to show any significance.

Tables 1-4 list the average monthly concentration for total organic carbon, nitrate, sulfate, and chlorides. Examination of the tables shows the variability of the data. Table 1 (total organic carbon concentration) shows that in many cases control plots have higher TOC concentration than the highest treatment and, in fact, the control concentration in the October application of 164 mg/l is the highest concentration of the entire experimental period. Further review of the table shows that concentrations which are high during one particular month suddenly decrease the following month and vice versa. This type of variability caused the problems in statistical analyses.

Table 2 (nitrate concentration) illustrates the same type of variability as Table 1. However, the highest concentration (144 mg/l) in this case occurs in the 45 ton/acre treatment in the split application. The control reaches a concentration of 59 mg/l during the fall in the October treatment and then decreases to 2 mg/l the next spring. The 45 ton/acre treatment in the August application reaches a high of 53 mg/l in June '69 only to decrease to 0 in the next two months.

Table 3 (sulfate concentration) shows the control in the split application with the highest concentration (591 mg/l). Concentrations in this table are also variable between months with high concentration being followed by much lower concentration in later months. Table 4 shows the 15 ton/acre treatment in the June application with the highest concentration of 115 mg/l. Following this application, however, no sample was produced by those plots. The variability shown in the other contaminant concentration is also prevalent in this table.

It was, therefore, the opinion of the investigators that no significant conclusions could be developed from the data obtained from the zero-tension lysimeters. Unfortunately, once the lysimeters were installed and manure applied, and other phases of the study initiated, it was not possible to make changes during the period the grant was in effect.

Table 1.

TOTAL ORGANIC CARBON
mg/l

	June application tons/acre				Aug. application tons/acre				October application tons/acre				Split (May/Aug) application tons/acre			
1968	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
May	15	13	15	21	60	34	14	20					29			17
June	14	13	15	16									9	9	14	12
July	23	39	40	21	72	40	41	48					30	20	16	33
Aug.	39	40	17	29	18	26	15	23	28	12	49	25	14	18	17	19
Sept.	22		18	9	21	29	40	65	24						50	46
Oct.	49		7	43	62		51	80		47		55				18
Nov.	51	102			61		55	43	164	74	42	56	110	31	18	27
Dec.	72	15			56		45	43				47	40		102	28
1969																
Jan.																
Feb.																
Mar.	17	13	3		144	85	19	34		22		26	9		75	22
Apr.		16	14		8		6	6	54		50		7		9	
May	47	83	27		28	27	100	103					30	21	124	51
June	27		26	52	54	50	55	48	22	34	5	18	25	42	25	20
July	5							40	9						84	
Aug.	12	16	18		20	27		21	16	20	5	14	16	11		
Sept.	17				24		18	24	7				13		20	24
Oct.	50	68						5		81		21				

Table 2.

NITRATE mg/l

	June application tons/acre				Aug. application tons/acre				October application tons/acre				Split (May/Aug) application tons/acre			
1968	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
May																
June		6	4			4	4						8	2	4	15
July	6		2	2			2			1					1	8
Aug.	23	3	14	25	36	2		4	5	24		6	1	3	45	2
Sept.				1			6		59						2	
Oct.																
Nov.																
Dec.																
1969																
Jan.																
Feb.																
Mar.																
Apr.		0	1		1		2	1	2		1		2		10	
May	0	5	1		2	1	4	0					0	5	2	0
June	28		1	3	8	6	23	53	13	45	16	83	1	20	29	31
July																
Aug.			34					0		104	0	109			52	
Sept.					0		38	0	0				37		8	144
Oct.																

Table 3.

SULFATE mg/l

	June application tons/acre				Aug. application tons/acre				October application tons/acre				Split (May/Aug) application tons/acre			
1968	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
May																
June		23	0	62		0	0						0	0	0	20
July	23	51	0	14		9	0			71			0		0	36
Aug.	0		0		38	70		80								28
Sept.																
Oct.																
Nov.																
Dec.																
1969																
Jan.																
Feb.																
Mar.																
Apr.		45	56		59		53	65	106		258		76		36	
May	42	31	16		61	59	109	43					24	11	102	45
June	133		35	144	57	80	69	140	28	138	16	89	53	46	78	110
July																
Aug.	67		80		62	173		38		99	44	99	591	58	200	50
Sept.	48	67	22		70		24	78	8	133		175	19		49	37
Oct.																

Table 4.

CHLORIDE mg/l

	June application tons/acre				Aug. application tons/acre				October application tons/acre				Split (May/Aug) application tons/acre			
1968	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
May																
June		0	1	88		0	0									
July	6	5	4	4		7	0			10			0	0	0	3
Aug.	14	7	10	28	33	7	0	15	5	4	0	5	0		0	3
Sept.	4		0	0	0	0	0	21	0				7	17	11	5
Oct.													2		3	0
Nov.																
Dec.																
1969																
Jan.																
Feb.																
Mar.																
Apr.																
May	20	115	8		17	33	24	20					10	59	32	
June	10		15	57	20	47			16	22		6	15	31		
July																
Aug.			58					55		18	4	4		29		
Sept.					5		3		1				14		5	56
Oct.																

CONCLUSIONS

Some important points should be stressed:

(1) Although the levels of TOC concentration are high, there are no significant differences between the control and treatments at any of the application times.

(2) Nitrate concentrations did exceed the limit set by the USPHS for potable water use. However, the concentrations are not significantly higher than those found by previous investigators (5) who also found these concentrations tend to decrease during lateral movement of ground water. No significant difference in NO_3 concentration could be found between the control and treatments.

(3) Sulfate and chloride concentrations never exceeded the limit set by the USPHS for potable water and no significant difference could be found between the concentrations of the control and treatments.

(4) All fecal coliform tests proved to be negative. When evaluating the results of this phase of the experimentation, it must be pointed out that the samples collected in the zero-tension lysimeters represent the actual pollutional load entering the ground water during the limited testing phase of the experiment.

Based upon the data obtained, it can be concluded that under the experimental conditions imposed, no ground water pollution actually occurred during the zero-lysimeter test phase. However, it should be noted that because of the extreme variability no statistically significant differences would be shown unless there were tremendous differences between treatments and the control. Therefore, it must be pointed out that there is still a great possibility that ground water contamination could occur. Thus, although the effectiveness of this method of solid waste disposal has been demonstrated, and the design and scale of the study would have been expected to yield important answers to the question of ground water pollution, the very erratic nature of the results prevents any conclusions as to the probable effect of the method on water contamination.

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TERMINATION REPORT: Laboratory Decomposition Studies and Salmonella in Excreta

Prepared by Melvin S. Finstein

Laboratory studies were designed to complement field experimentation in aspects of the Plow-Furrow-Cover method of excreta disposal. In this context, laboratory studies have the inherent disadvantage of being somewhat artificial, and of uncertain applicability to field conditions. The advantages of laboratory experimentation, however, make it possible to control temperature and salt content of the soil-excreta mixtures and feasible to study the effects of a wide range of excreta loadings, and repeated loads of waste. In this manner, the limitations of the soils' capacity to serve as a disposal medium were more fully explored than would be feasible by field experimentation alone.

For the sake of clarity, most of the graphs are presented without the data points shown. The numerous treatments in individual experiments generated too many data points to be shown in the graphs.

Materials and Methods

Soil

Soil for laboratory studies was taken from sites intended for field trials of the Plow-Furrow-Cover disposal method. These areas had not recently been manured. Soil was removed from the Ap horizon of the profile, passed through a sieve to remove large particles and stored in a moist condition (4). Water was added occasionally to prevent dessication. The characteristics of the soils used are summarized in Tables 1, 2, 3, and 4.

Excreta

To collect chicken excreta, nonabsorbent paper was placed under cages housing egg-laying White Leghorns at the Rutgers Poultry Department. These fowl were fed a "normal" diet of mash. The excreta which accumulated during a 4-day period was air dried under forced draft, ground in a Wiley Mill, and stored in a dessicator at room temperature. During the course of the experiment, two batches of excreta were prepared; their characteristics are given in Tables 5 and 6.

When needed for experimentation, soil and excreta were combined in the desired proportions and mixed thoroughly. To the mixture was added sufficient water to bring the soil to 70 percent field capacity and reconstitute the excreta to its original moisture content.

Table 1

Physical characteristics of collected soils

Collection Site	Soil Texture	Mechanical Analysis* % sand	silt	clay	% Moisture** at field capacity
Cologne	loamy sand	86	8	6	12.0
Adelphia	sandy loam	75	17	8	23.4
New Brunswick	sandy loam	70	20	10	20.2
Flanders	loam	80	48	22	30.2

*Determined by modified Bouyoucos method.

**% moisture = $\frac{\text{wet wt.} - \text{dry wt.}}{\text{wet wt.}} \times 100$.

Field capacity determined by procedure of Black (3).

Table 2

Kjeldahl-nitrogen, total organic carbon, and

pH of collected soils

Collection Site	Kjeldahl-nitrogen[1]	total organic carbon[2]	pH[3]
	mg/g	mg/g	
Cologne	-	4.8	7.2
Adelphia	1.85	7.5	6.8
New Brunswick	0.98	5.1	6.2
Flanders	-	9.0	7.4

[1] Determined by micro-Kjeldahl method of Bremner in Black (3).

[2] Determined with a Beckman Carbon Analyzer after sampler was reduced to colloidal size by grinding and homogenization.

[3] Determined an 1:1 soil to water slurry.

Table 3

Macro-nutrient content of the soils*

Collection Site	ppm Magnesium	ppm Phosphorous	ppm Potassium	ppm Calcium
Cologne	333	210	567	840
Adelphia	322	154	525	784
Flanders	406	189	578	784

*Determined in Rutgers Soil Testing Laboratory.

Table 4

Micro-nutrients content of the soils*

Collection Site	ppm Iron	ppm Zinc	ppm Copper	ppm Magnese
Cologne	75	30	8.0	18.0
Adelphia	60	25	7.5	18.0
Flanders	46	20	5.6	26.0

*Determined in Rutgers Soil Testing Laboratory.

Table 5

Characteristics of air dried chicken excreta

Batch	% Solids[1]	pH	total organic carbon[2]	Kjeldahl-nitrogen[2]
1	23.3	5.3	202	57.53
2	23.7	5.4	216	58.32

[1] % solids = $\frac{\text{dry wt}}{\text{wet wt}}$

[2] mg/g air dried excreta

Table 6

Composition of chicken excreta

Characteristic	%	Milligrams per g air dried excreta	Method of analysis
solids	23.7		
moisture	76.3		
volatile solids	73.7	737.0	Standard Methods
ash	26.3	263.0	" "
calcium		18.8	Auto analyzer
chloride		55.1	Hach Chemical
copper		0.7	" "
iron		0.6	" "
magnesium		4.8	Auto analyzer
maganese		0.7	Hach Chemical
orthophosphate		23.0	" "
polyphosphate		26.8	" "
potassium		13.5	Auto analyzer
silicon		2.2	Hach Chemical
sodium		3.0	Auto analyzer
sulfate		25.7	Hach Chemical
nitrogen		58.3	Micro-Kjeldahl
organic carbon		208.0	Beckman Analyzer

Biometer

The "biometer" apparatus developed by Bartha and Pramer (2) was used as the reaction vessel for the respirometer studies. It was modified for our purposes to have two sidearms instead of one, as originally described. The features of the biometer are shown in Figure 1.

The desired soil-excreta mixture was put into the main chamber of the biometer. Periodically the flask atmosphere was renewed with CO_2-free air by removing the stopper from the ascarite filter and opening the cock. Each sidearm received 10 ml. of reagent consisting of either KOH of known strength (usually 0.25 N) to trap evolved CO_2, or 0.6 N H_2SO_4 to trap NH_3. Removal of spent reagent and its replacement with fresh reagent was accomplished with a calibrated syringe fitted to the syringe needle. Incubations were carried at 20°C unless otherwise noted.

Determinations of CO_2 and NH_3

To the spent KOH solution was added excess $BaCl_2$ dissolved in CO_2-free water and 2 drops of phenolphthalein indicator solution. Residual hydroxide was estimated by titration with HCl to the colorless end point, and this value was used to calculate the amount of CO_2 absorbed during the previous incubation period.

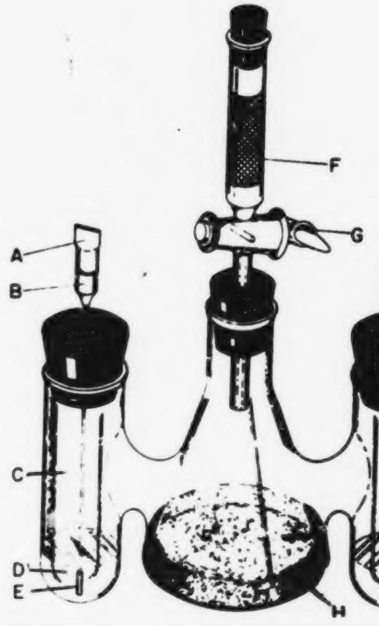
The amount of ammonia absorbed in the H_2SO_4 reagent was estimated by steam distillation. A measured volume of H_2SO_4 solution containing between 0.2 and 2 mg NH_4-N was placed into a Markham still, followed by 10 ml. of Na_2SO_3-NaOH reagent. A minimum of 15 ml. was distilled into a boric acid mixed-indicator solution, which was titrated with 0.01 N potassium biniodate.

Preliminary Experimentation

A preliminary trial was necessary to test the suitability of the biometer for use in studies involving chicken excreta. It was not known how frequently it would be necessary to replenish the air supply in the biometer, especially during the initial stages of decomposition when an intense oxygen demand was expected. Since the initial stages of decomposition were of interest here, as opposed to long term studies anticipated later, the Warburg apparatus was suitable for this preliminary trial.

Each 125 ml. Warburg flask received 10 grams of Nixon sandy loam, mixed with excreta to give the following soil-excreta ratios: 10:0, 10:.01, 10:.1, 10:2, 10:3, 10:4, 10:5, 10:7.5, and 10:10. KOH was added to the center-well to absorb CO_2. The most active oxygen uptake occurred with the soil-excreta ratio of 10:3 (Figure 2). At this loading the maximum rate of oxygen uptake was about 2 ml. per hour.

Figure 1. Modified biometer after Bartha and Pramer (1965).



KEY:

A - syringe needle stopper

B - 15 gauge syringe needle

C - 50cc tube

D - collecting solution

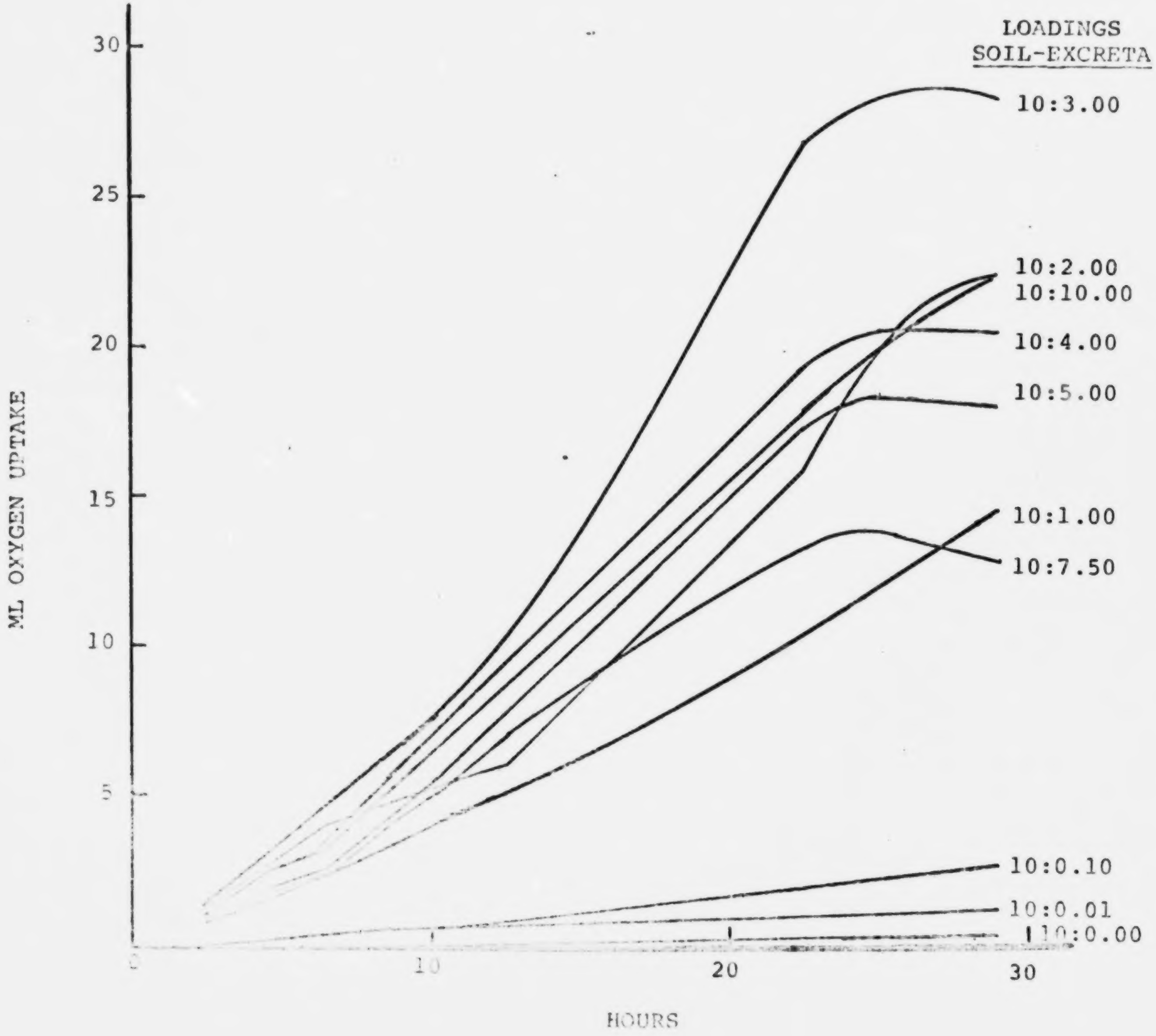
E - polyethylene tubing

F - Ascarite filter

G - Ascarite filter stopcock

H - soil-excreta mixture

Figure 2. Oxygen uptake by soil-excreta mixtures as measured by manometer (Warburg) technique.



Since the biometer contains on the order of 50 ml. oxygen (total biometer volume about 300 ml.) replenishment of the air supply two times a day during the initial stages of incubation would provide a margin of safety to insure an adequate supply of oxygen at all times. The biometer was therefore judged to be suitable for our purposes.

One additional point was suggested by the Warburg study. Upon opening the flasks a strong NH_3 odor was noted, and verified by inserting into the flask atmosphere a strip of filter paper wetted with Nessler's reagent. Evolution of large amounts of NH_3 for which no means of removal had been provided may have interfered with the measurement of O_2 uptake, contributing to the abrupt leveling-off noted in some of the curves. The magnitude of NH_3 evolution emphasized the importance of measuring this parameter of excreta decomposition, and from this observation stems the decision to procure biometers having two sidearms.

Evaluating the Precision of Measurements

To evaluate the precision of measurements obtainable with the biometer when chicken excreta undergoes decomposition, additional preliminary trials were undertaken. A limited number of single-arm biometers were available at this time, but only one double-arm biometer. Therefore, separate trials were conducted, the first to measure CO_2 evaluation and the second NH_3. A mixture consisting of soil and excreta in a ratio of 10:1 was placed into biometers and incubated at 20^oC. The cumulative amount of the CO_2 is recorded in Figure 3 and the rate in Figure 4. Ammonia data is presented in Figures 5 and 6.

The cumulative CO_2-C evolution during the 20 day incubation ranged from 81 to 119 mg., with a mean of 94 ± 16 mg (1 standard deviation). The confidence interval about the mean at the 95% level was 94 ± 20 mg. That is, unless this was the one unusual sample in 20, the population mean is within this range.

An examination of Figures 3 and 4 indicated that the variation among biometers receiving the same treatment, when used to monitor CO_2-C evolution was slight and that the pattern of CO_2-C evolution was the same.

The data from days 5, 9.4 and 19.5 was used to calculate an analysis of variance (ANOVA), the results of which are in Table 7. The ANOVA calculations indicated that there were differences between biometers. However, the square root (6.35) of the ANOVA error mean square (40.37) is really the best measure of error and negates the importance of differences between biometers by the F test. Considering the rather small measure of error, the heterogenity of soil and excreta, and the difficulties of obtaining perfectly uniform soil-excreta mixtures, it appeared that three replications would be adequate to assess the variability which exists among biometers.

Figure 3. Cumulative CO_2-C evolved by a 10:1.0 soil-excreta mixture incubated at 20°C. All biometers single arm except where noted.

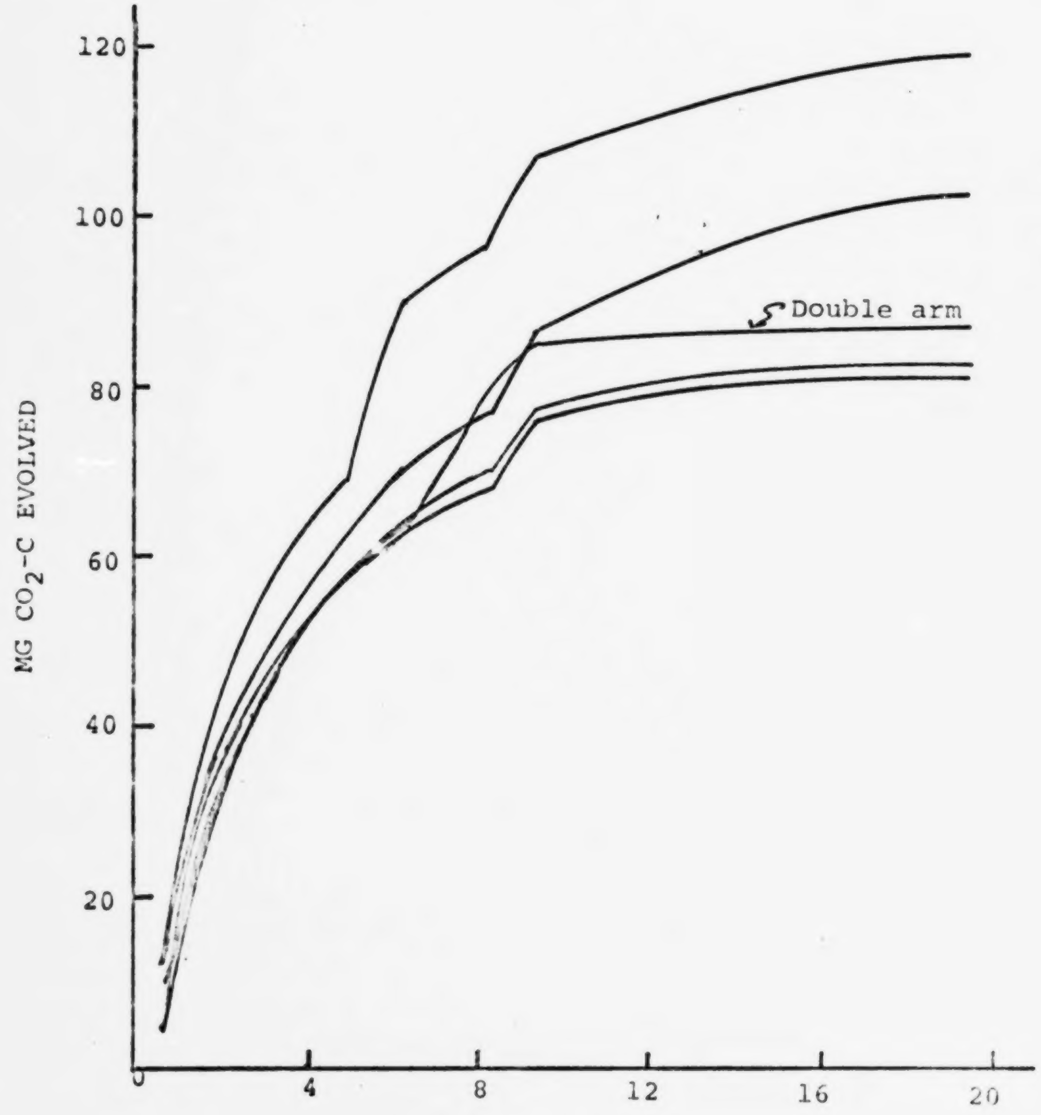


Figure 4. Rate of CO_2-C evolution per day of incubation by a 10:1.0 soil-excreta mixture incubated at 20°C. All biometers single armed except where noted.

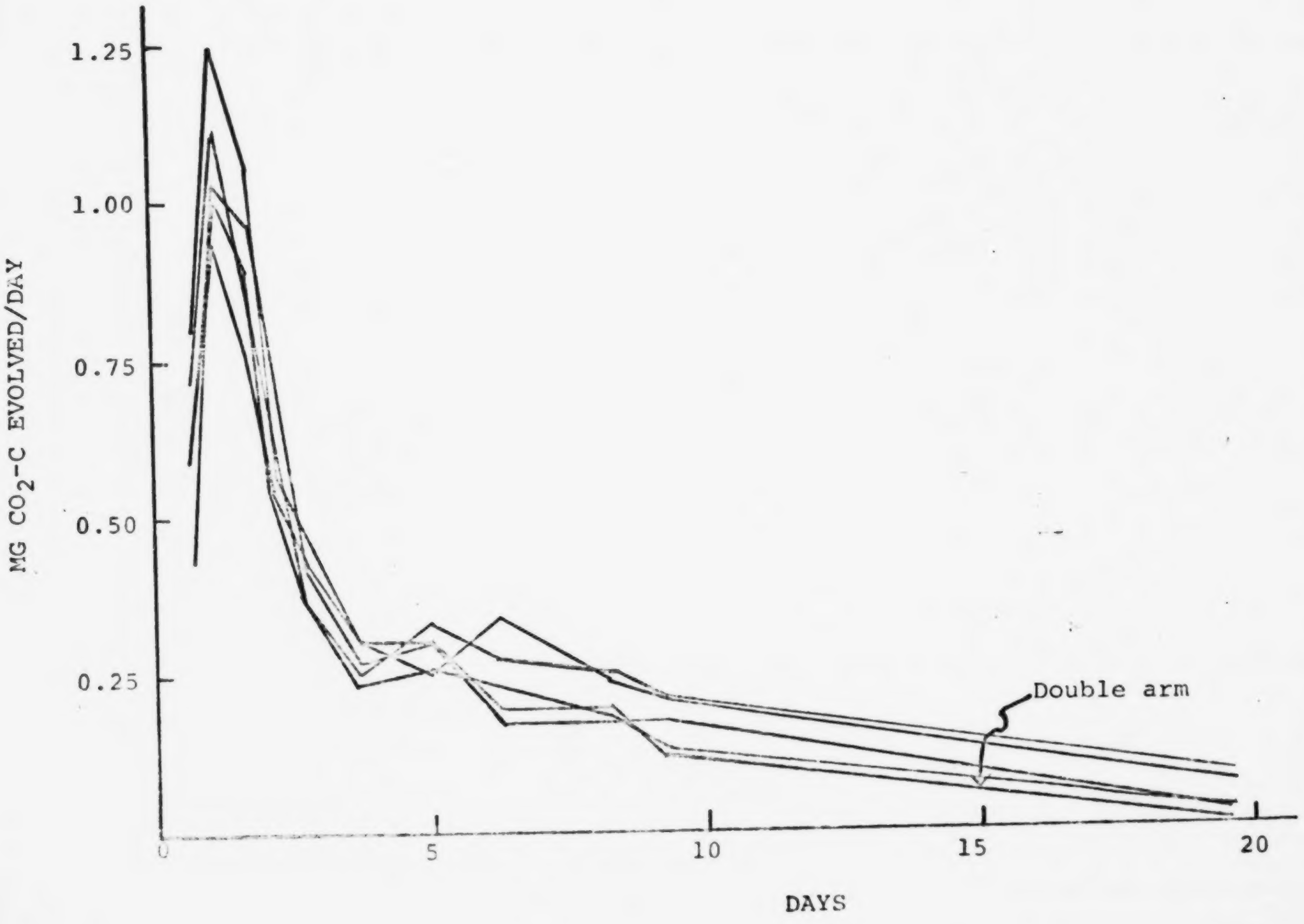


Figure 5. Cumulative NH_3-N evolved by a 10:1.0 soil-excreta mixture incubated at 20°C. All biometers single armed.

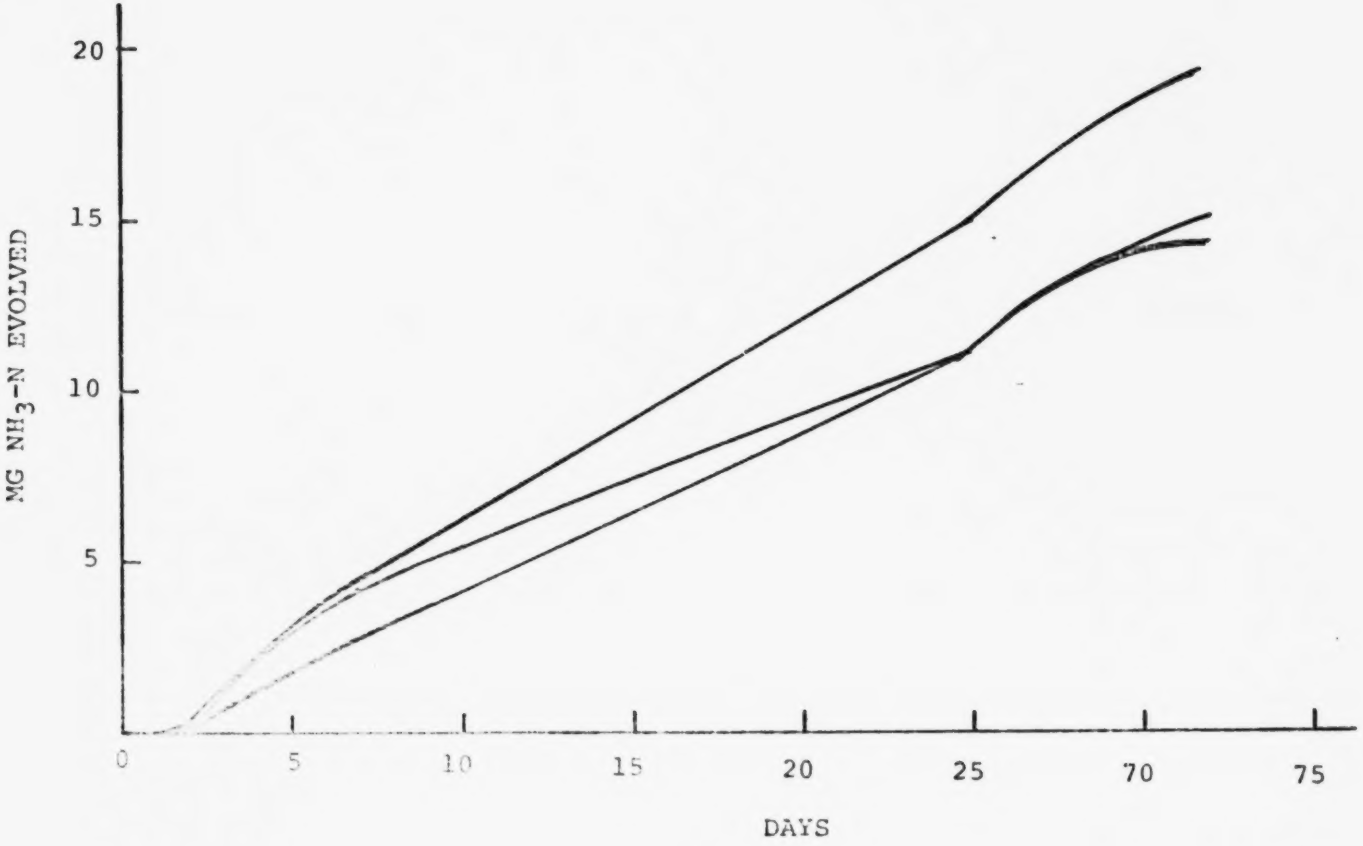


Figure 6. Rate of NH_3-N evolution per day of incubation by a 10:1.0 soil-excreta mixture incubated at 20°C. All biometers single armed.

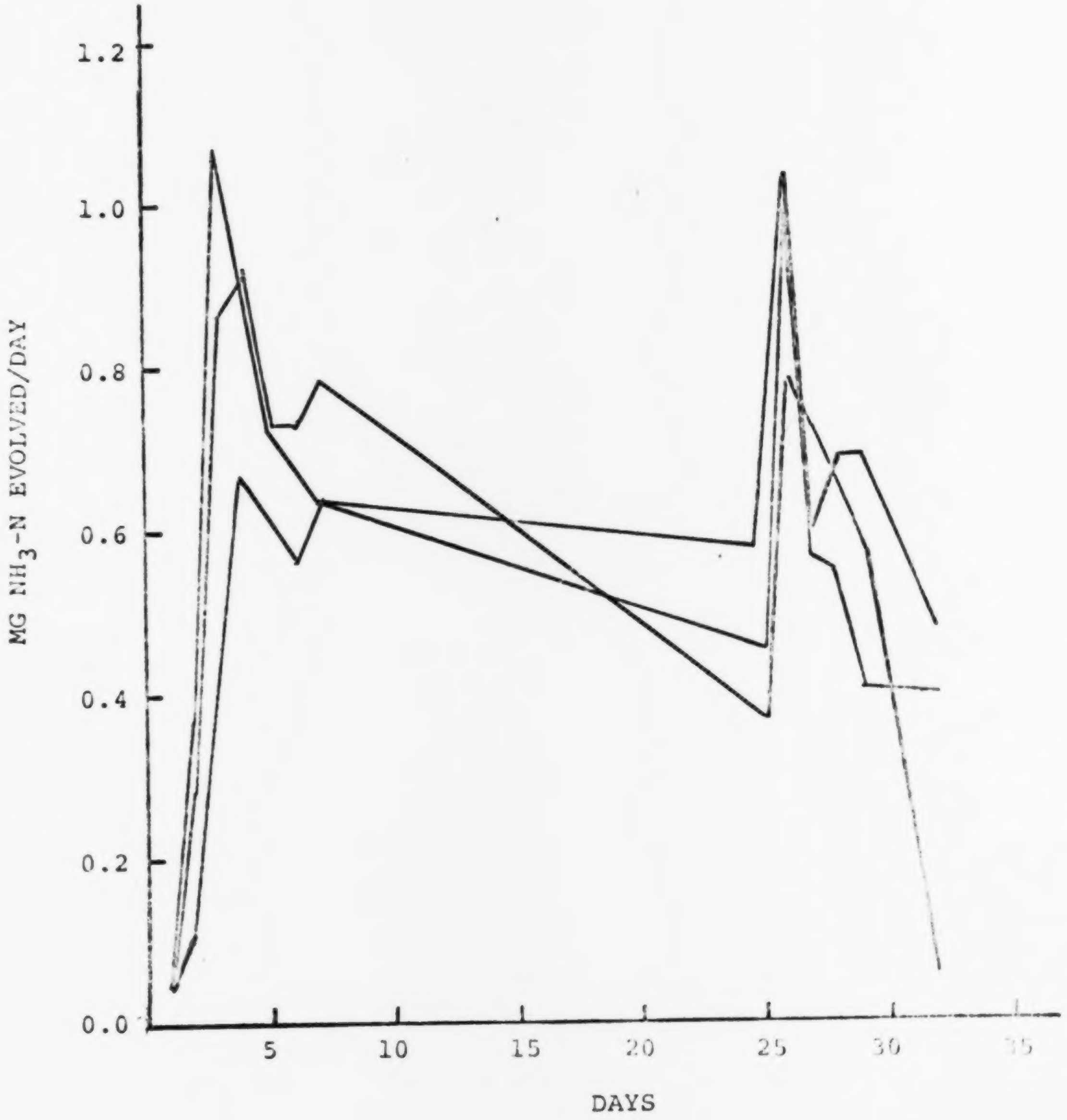


Table 7

ANOVA table for mg CO_2-C evolved in replicate biometers

Variation	Degrees of freedom	Sum of squares	Mean squares	F calculated	F book[1]
Total	14	4822.34			
Days	2	3025.07	1512.54	37.47**	8.65
Biometers	4	1474.30	368.58	9.13**	7.01
Error	8	322.97	40.37		

[1] 10.0% significance level.

**differences were significant at the 1% probability level.

Based on the amount of organic carbon in the added excreta and the amount of CO_2 collected, it is estimated that 47 percent of the organic carbon was volatilized during the incubation. Decomposition, as measured by CO_2 evolution, was most intense during the first three days of incubation. On the average the maximum rate of evolution was about 1 mg. CO_2-C per hour, and this occurred between the 14th and 26th hour of incubation. Thereafter, activity declined to a relatively low level.

From Figures 3 and 4 it is clear that the H_2SO_4 in the double sidearm did not seriously interfere with the monitoring of CO_2-C evolution, since the CO_2-C data for this prototype biometer was not unique.

The ascarite barrier prevented the entrance of atmospheric CO_2 to the biometer while the air supply was being replenished, thus eliminating a potential error. No barrier against NH_3 was available, however, and the possibility of introducing significant amounts of this gas had to be considered. For this reason a biometer containing distilled water instead of soil and excreta was included in the experiment, and monitored for NH_3. None was detected, indicating that the level of NH_3 in the laboratory atmosphere was not sufficient to introduce a detectable error.

The cumulative evolution during the 20-day incubation ranged from 14 to 19 mg. NH_3-N with a mean of 16 ± 2 mg. (1 standard deviation). The confidence interval about the mean at the 95 percent level was 16 ± 5 mg. That is unless this was the one unusual sample in twenty, the population mean is within this range.

An examination of Figures 5 and 6 indicated that the variation among biometers receiving the same treatment when used to monitor NH_3-N evolution was slight and that the pattern of NH_3-N evolution was the same.

An ANOVA was calculated with the data from all the observations and the results appear in Table 8. The ANOVA indicated that there was a difference between biometers at the 1 percent level of significance. However the square root (1.12) of the ANOVA error mean square (1.27) is really the best measure of error and negates the importance of the differences between biometers by the F test. Considering the rather small measure of error, the heterogeneity of soil and excreta and the difficulties of obtaining perfectly uniform soil excreta mixtures, it appeared that three replications would be adequate to assess the variability which exists among biometers.

The similarity between the results of the CO_2 and NH_3 evolution evaluations indicate that three replications are adequate to assess the variability which exists.

Table 8

ANOVA table for mg NH_3-N evolved by three replicate biometers

Variation	Degrees of freedom	Sum of squares	Mean squares	F calculated	F book[1]
Total	38	1624.77			
Days	12	1550.56	129.21	101.74**	3.12
Biometers	2	43.85	21.92	17.26**	5.72
Error	24	30.36	1.27		

[1] 1.0% significance level.
**differences were significant at the 1% probability level.

Based on the amount of Kjeldahl nitrogen in the added excreta and the amount of NH_3-N recovered, it is estimated that 28 percent of the nitrogen initially present was volatilized during incubation.

Intense evolution of NH_3 commenced at about the fifth day of incubation, declined somewhat, and peaked again on about day 25. Ammonia evolution appeared to be more sustained than CO_2 evolution.

In summary, these preliminary experiments indicate that the biometer would be a satisfactory apparatus to monitor the CO_2 and NH_3 evolved by an excreta-soil mixture provided that reagents for trapping the gases, and air were replenished at frequent intervals. The statistical considerations suggest that three replications for each treatment would be adequate to account for the variability which exists between biometers.

Effect of Excreta Loading on Decomposition

Mixtures of Adelphia sandy loam and chicken excreta were prepared to study the effect of excreta concentrations on decomposition. Double sidearm biometers were employed to permit the monitoring of CO_2 and NH_3 evolution simultaneously. Daily readings were taken during the first half of a 24 day incubation period and at 2 or 3 day intervals thereafter.

The amount of CO_2 evolved was directly related to the concentration of excreta (Figure 7); that is, the higher the concentration of excreta the greater the magnitude of CO_2 evolved. For example, at a soil-excreta ratio of 10:10 a total of 570 mg, CO_2-C was collected whereas the comparable value with a 10:1 ratio was 155 mg. The percent decomposition, however, was inversely related to excreta concentration (Figure 9). This is exemplified by the fact that in the 10:1 treatment 57 percent of the added organic carbon was accounted for as CO_2, but only 29 percent in the treatment having the most concentrated excreta (soil-excreta ratio of 10:10). A sharp drop in percent decomposition is evident at soil-excreta ratios higher than 10:2. A preponderance of soil relative to excreta apparently favors the rapid decomposition of the excreta.

Only about 17 percent of the soil organic matter in the control flasks (soil only) was recovered as CO_2. This is indicative of the relative stability of native soil organic matter.

Intensive NH_3 evolution was somewhat delayed at the higher loadings, compared to the treatments containing less excreta (Figure 8). In the latter stages of incubation, however, a direct relationship was established between the absolute amount of NH_3 recovered and the amount of organic nitrogen provided in the excreta. The relationship between NH_3 evolved per unit organic nitrogen was similar to the CO_2-C organic carbon relationship, although the differences between treatments was less marked for nitrogen (Figure 9).

As judged by both CO_2 and NH_3 evolution, most rapid decomposition was favored at soil-excreta ratios between 10:1 to 10:2 as compared to the higher loadings. As a point of reference, the 10:2 ratio corresponds to about 800 tons fresh excreta per acre, assuming 2 million pounds of soil per acre-furrow-slice.

Figure 7. Cumulative CO_2-C evolved by various soil-excreta mixtures incubated at 20°C. Average of three replications.

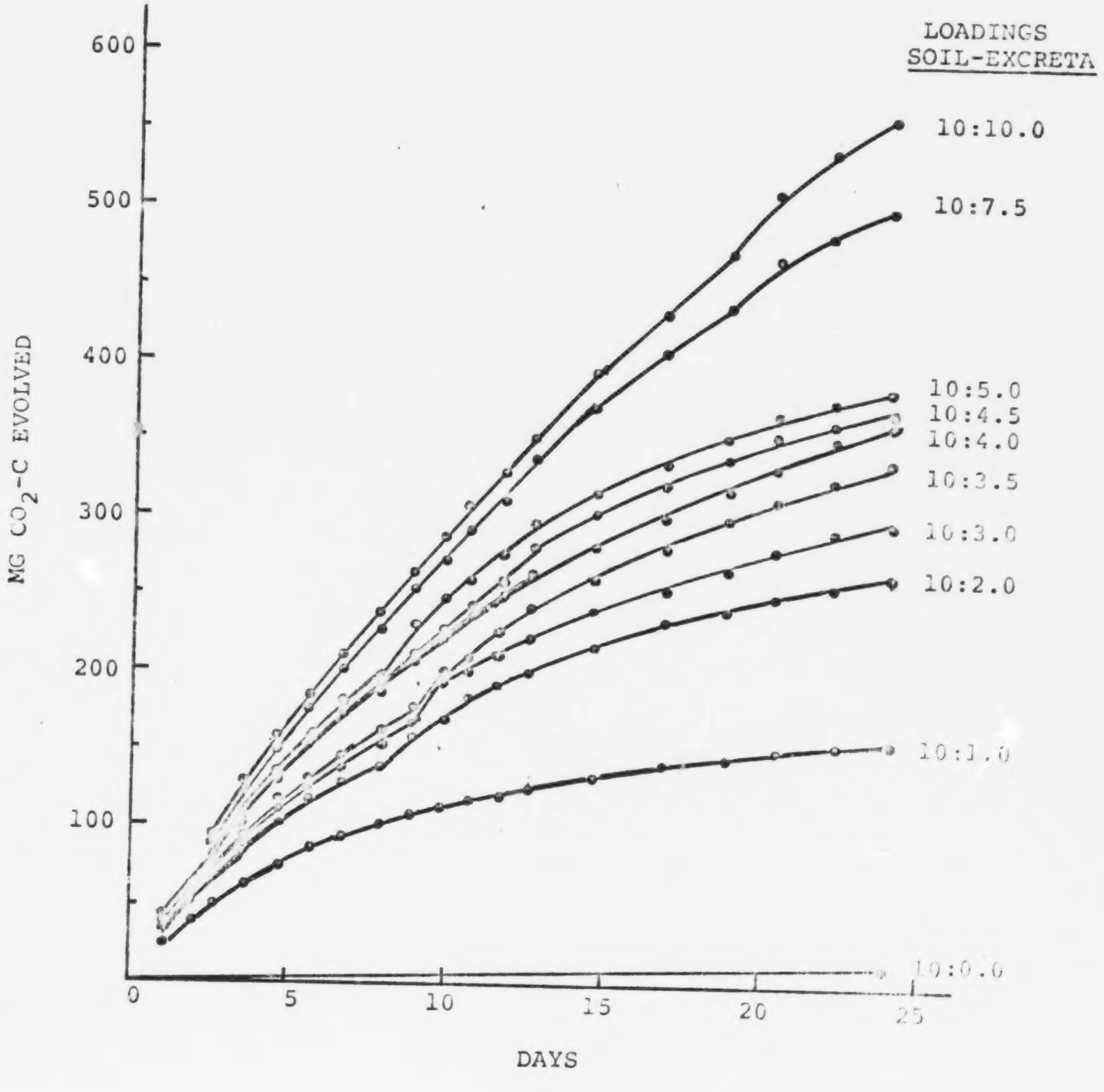


Figure 8. Cumulative NH_3-N evolved by various soil-excreta mixtures incubated at 20°C. Average of three replications.

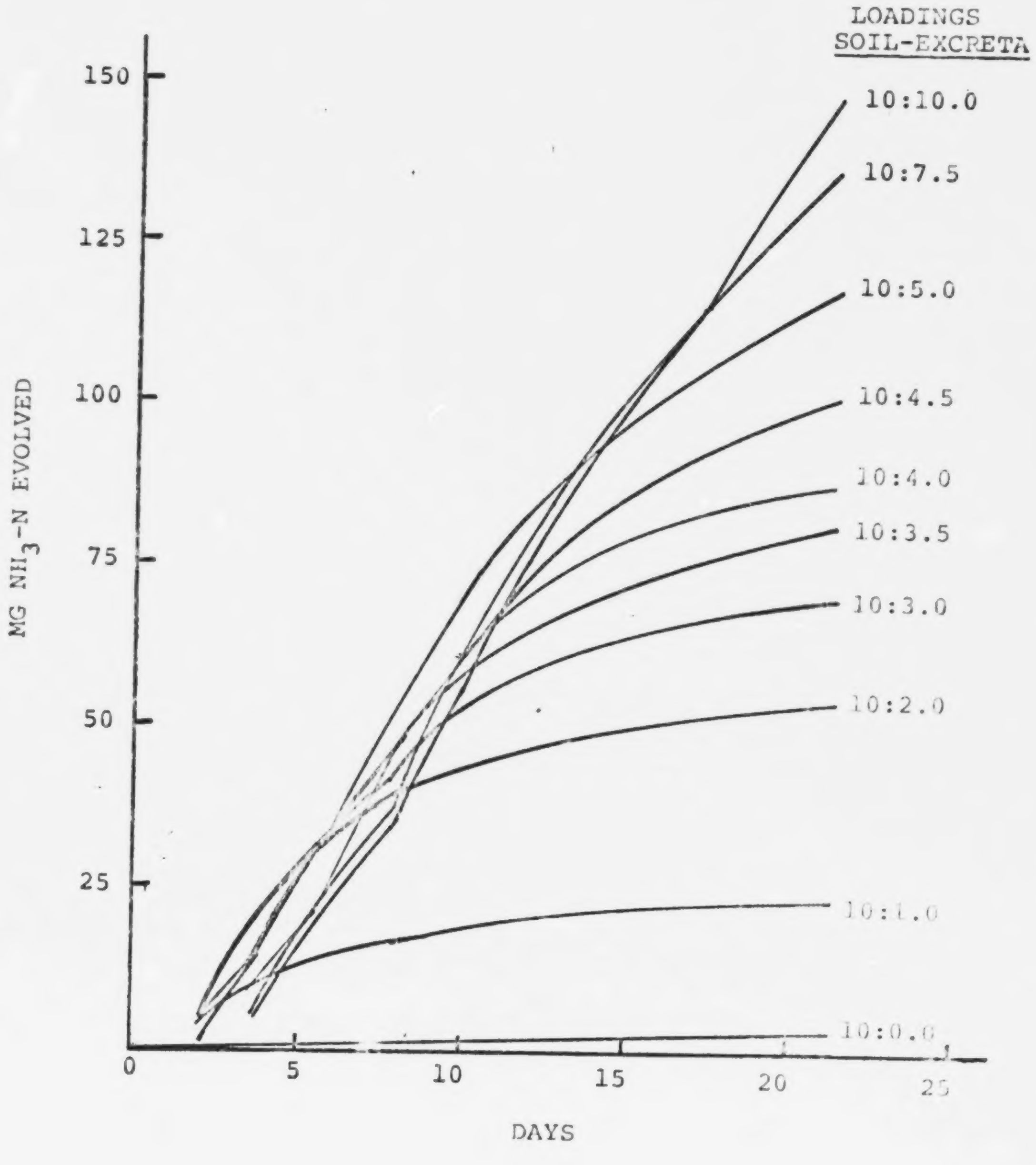
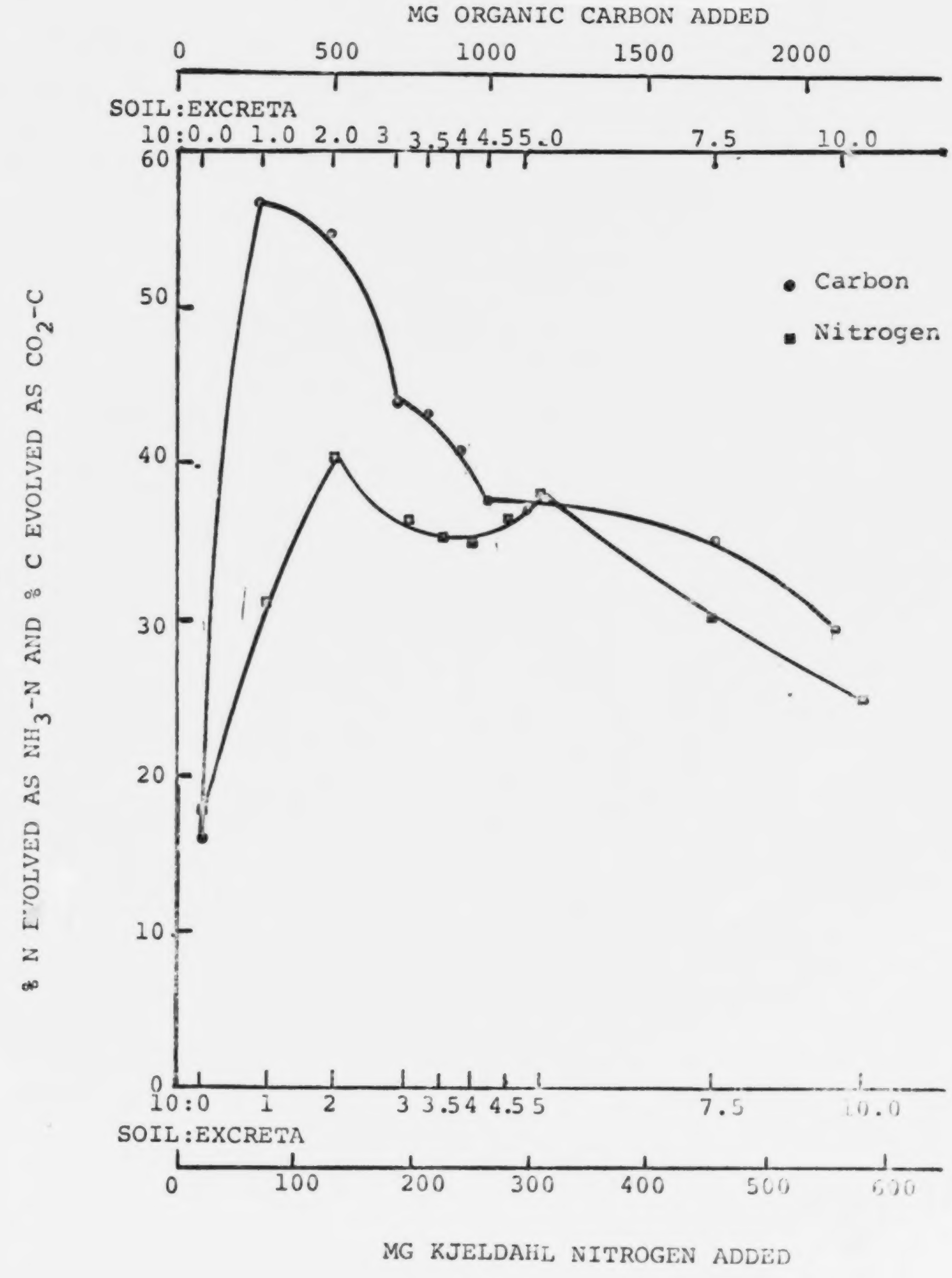


Figure 9. Percent carbon and nitrogen added evolved as CO_2-C and NH_3-N after 22 days incubation at 20°C. Average of three replications.



Effect of Excreta Loading, Temperature and Successive Excreta Load on Decomposition

Three parameters of importance to the use of the Plow-Furrow-Cover method, and the interactions among these parameters, were studied in an experiment. Excreta was incorporated into Adelphia sandy loam and carbon dioxide and ammonia evolution were monitored simultaneously by use of double sidearm biometers. Soil loading ratios of 10:1 and 10:2.5 were chosen on the basis of previous results; at ratios of 10:2 and wider, the percent loss of carbon and nitrogen was at a maximum, whereas these percentages declined when soil and excreta were combined in narrower ratios. Incubation temperatures of , 12, and 20°C. were chosen on the basis of data collected by Rahn (1966); the 4° to 20°C. range is representative of New Jersey soils at a depth of 8 inches throughout the year. Three successive loads of excreta of a magnitude identical to the initial load were applied: the first at the initiation of the experiment, the second 52 days later, and the third after a total of 132 days incubation. The second and third loads were applied when the rates of decomposition slowed perceptably. The second and third loads of excreta were thoroughly mixed with the material already in the flasks. The control flasks were mixed and moisture added as required. Each treatment was run simultaneously in three biometers. The experimental design is summarized in Table 9.

The cumulative values for CO_2 evolution over the entire experimental period are graphed in Figures 10a, 10b, and 10c. Each graph was restarted at zero CO_2 evolved at the time corresponding to the addition of fresh excreta. Some tentative conclusions were reached by visual inspection of the graphs.

All three successive loads behaved similarly at the intermediate temperature, and little change in the pattern of CO_2 evolution was evident regardless of previous history. In contrast, at 4°C. the extent of CO_2 evolution increased during the second and third successive loads relative to the first load; this occurred with both excreta loadings (10:1 and 10:2.5). Somewhat more complicated is the behavior at the highest temperature tested. The initial and second load at 20°C. behaved similarly at a loading of 10:1, but CO_2 evolution increased during the third loading. At the 10:2.5 loading ratio, more CO_2 was evolved during the second and third successive loads than during the first load.

Because this experiment involved successive loads of excreta, the absolute amount of CO_2 evolved, as shown in the preceding figures, may be less meaningful than the portion of the organic carbon added which was volatilized as CO_2 during the incubation. Therefore, the data was converted to the percent of the organic carbon added evolved as CO_2.

Table 9

Experimental Design to Determine Effects of Excreta Loadings, Temperature and Successive Loadings on the Decomposition of Excreta as Measured by CO_2 and NH_3 Evolution

Treatment number	Temperature of Incubation	Ratio of soil: excreta	Number of successive excreta loads
1a	4°C	10:0	1,2,3
b	"	"	
c	"	"	
2a	"	10:1	1,2,3
b	"	"	
c	"	"	
3a	"	10:2.5	1,2,3
b	"	"	
c	"	"	
4a	12°C	10:0	1,2,3
b	"	"	
c	"	"	
5a	"	10:1.0	1,2,3
b	"	"	
c	"	"	
6a	"	10:2.5	1,2,3
b	"	"	
c	"	"	
7a	20°C	10:0	1,2,3
b	"	"	
c	"	"	
8a	"	10:1.0	1,2,3
b	"	"	
c	"	"	
9a	"	10:2.5	1,2,3
b	"	"	
c	"	"	

Figure 10a. Cumulative CO_2-C evolved by various soil-excreta mixtures receiving three successive loads and incubated at 4°C. Average of three biometers.

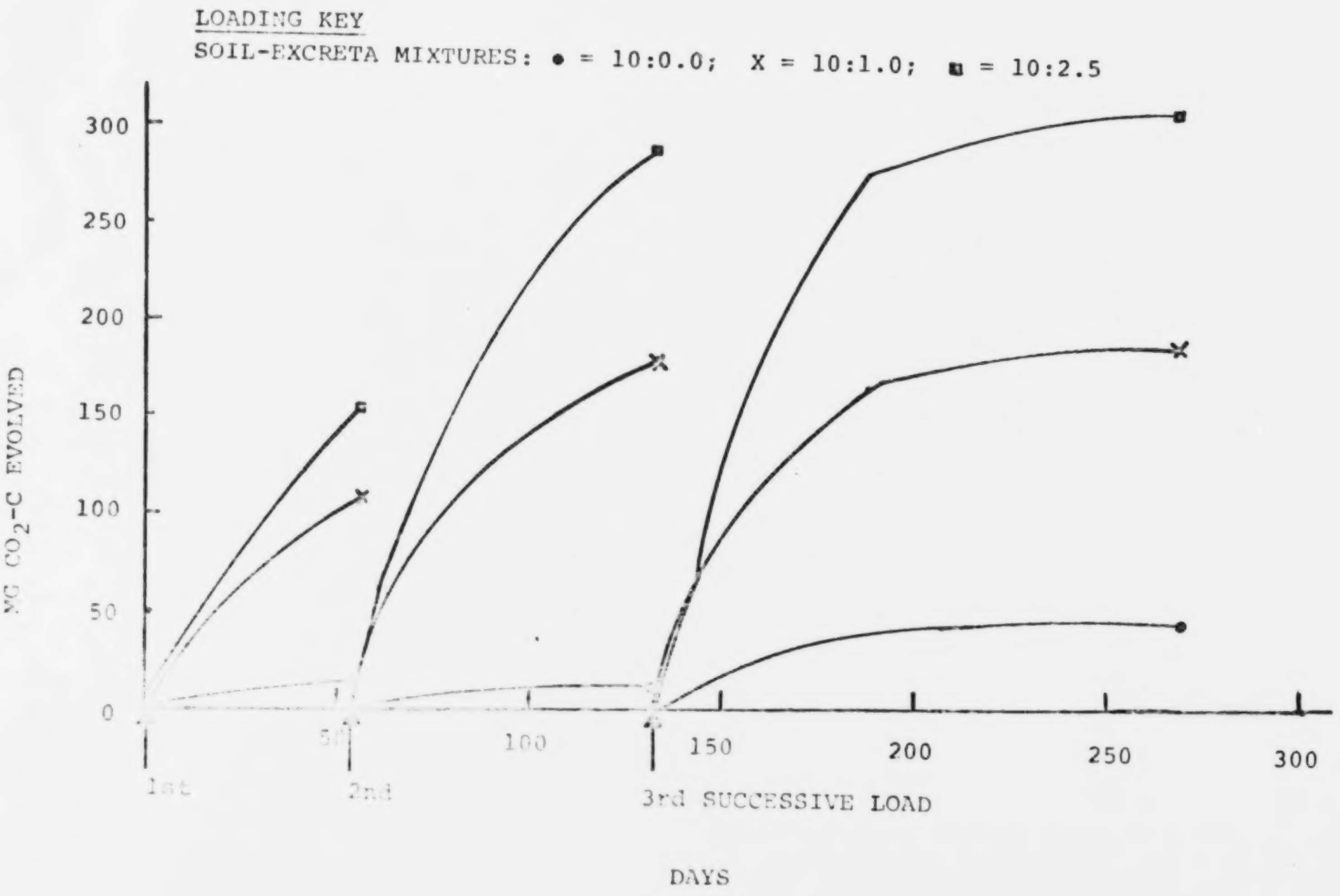
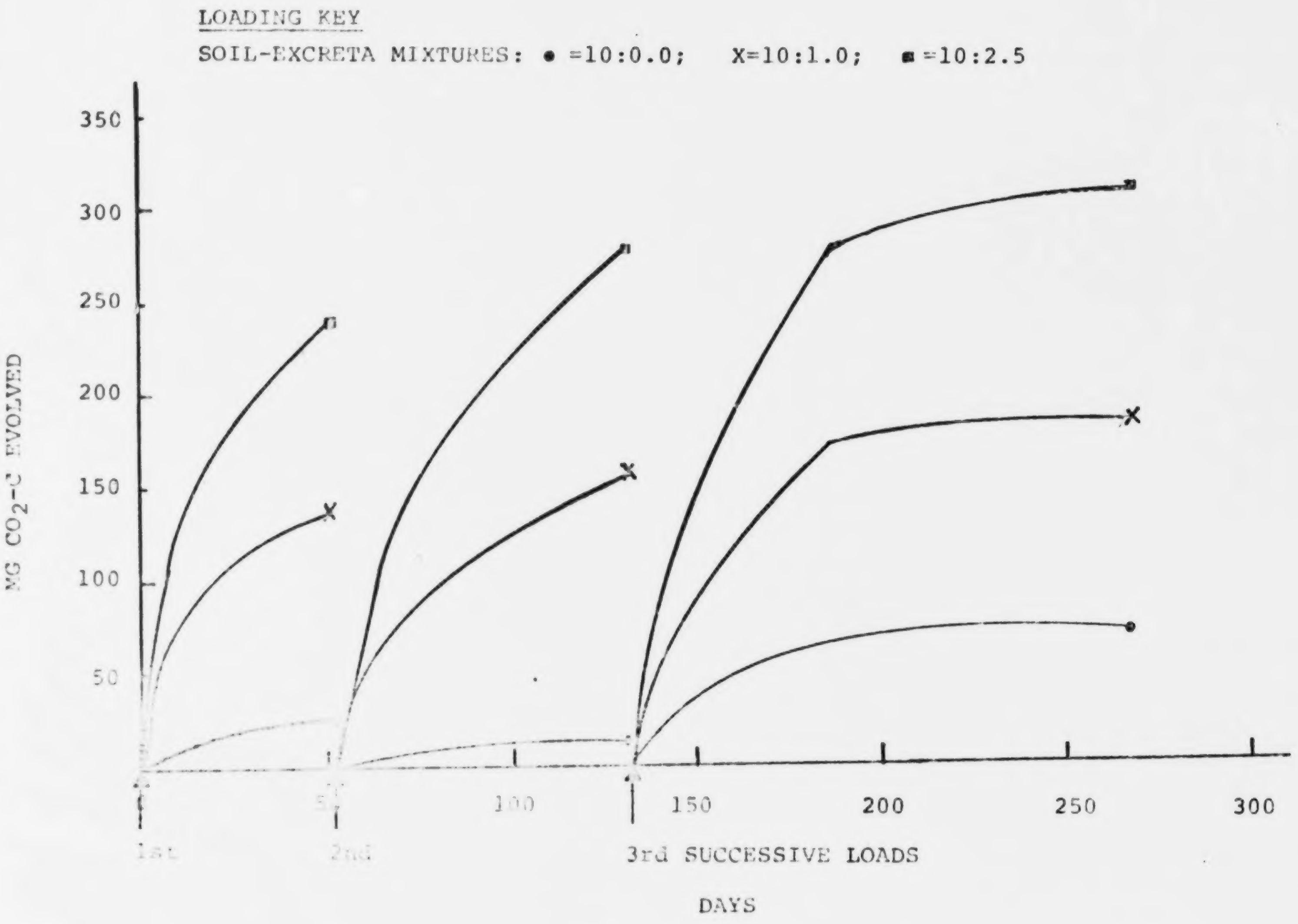


Figure 10b. Cumulative CO_2-C evolved by various soil-excreta mixtures receiving three successive loads and incubated at 12°C. Average of three biometers.



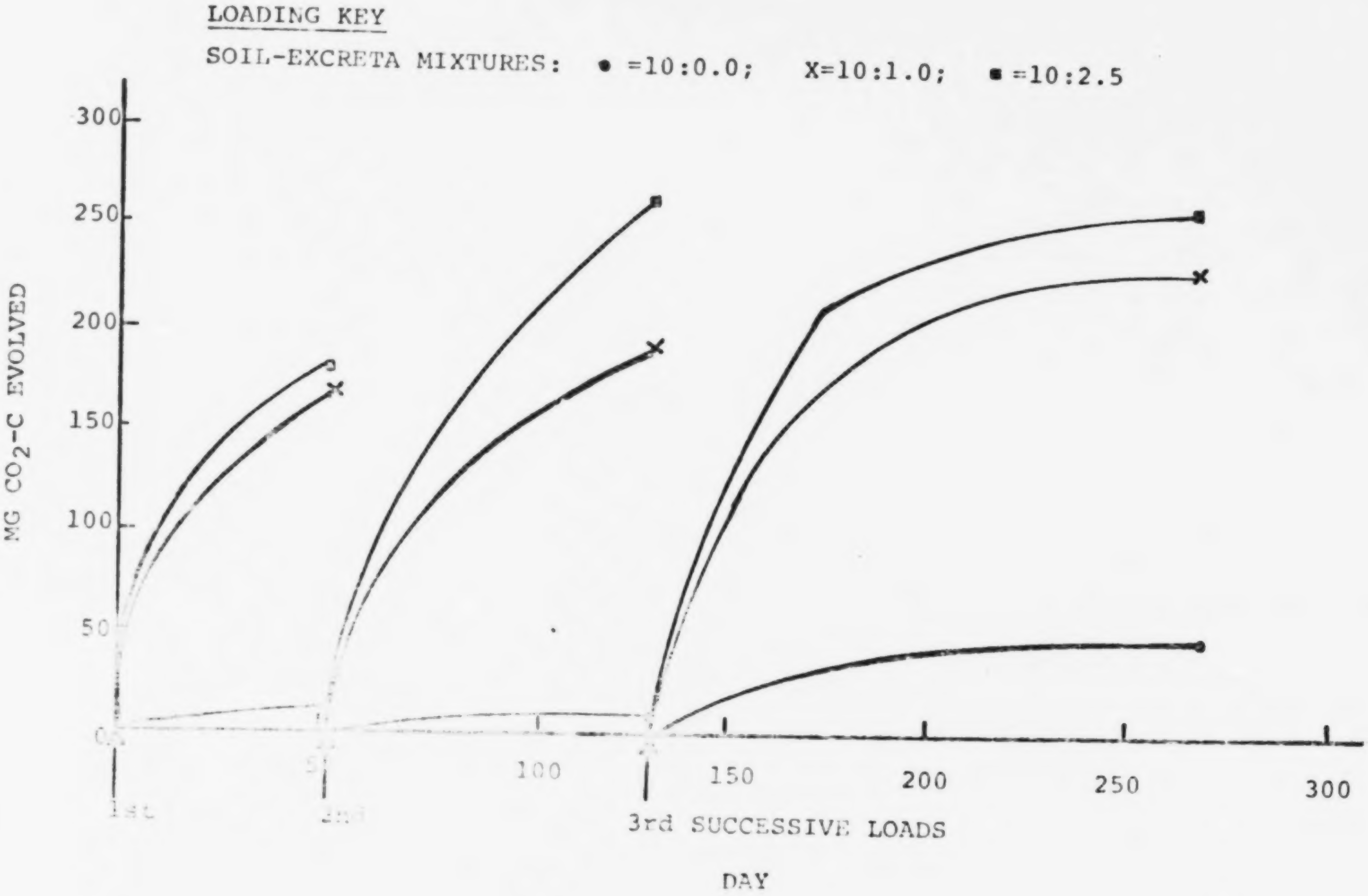


Figure 10c. Cumulative CO_2-C evolved by various soil-excreta mixtures receiving three successive loads and incubated at 20°C. Average of three biometers.

This manipulation was carried out on the data for the terminal day of incubation for the first and second loads, and for the 56th day for the third successive load. The last was chosen so that all three successive loads had undergone similar incubation periods.

$$\text{\% of carbon added to system evolved as } CO_2\text{-C} = \frac{CO_2\text{-C evolved} \times 100}{\text{Excreta org-C \& soil org-C}}$$

Excreta and soil organic-carbon was determined by complete combustion. The excreta organic carbon term includes the residual from previous excreta loads, where applicable. Residual was calculated by subtracting CO_2-C evolved from the organic carbon originally added. The converted data appears in Table 10 and Figure 11.

Although the absolute amount of carbon volatilized was greater at the higher loadings (Figures 10b and 10c), the percent volatilized was substantially greater at the lower loading (Figure 11). At the 10:1 loading an average of 49 percent of the added organic carbon was recovered as CO_2, whereas the comparable value for the 10:2.5 loading was 34 percent. These averages are calculated from the values from all the temperatures tested and for all three successive loads.

The complexities of the data required statistical analysis to permit a fuller assessment of the results. For reasons noted above, use of data converted to percent organic carbon evolved as CO_2 was preferred. An ANOVA would evaluate the relative importance of the different sources of variation. The ANOVA (Table 11) indicated that there were two two-way interactions, temperature x successive loads and loading x successive loads, that were significant at the 1 percent level. Temperature x loading was significant at the 5 percent level. The data representing these interactions are graphed in Figure 12; each interaction is discussed separately.

Temperature x excreta loading. In this interaction, the percent CO_2 evolved increased with an increase in temperature from 4 to 12°C. at both loading ratios. Likewise, from 12° to 20°C. the percent carbon volatilized increased for the 10:1 loading; decomposition was less complete, however, with the 10:2.5 loading at 20°C. relative to 12°C.

Temperature x successive loads. The percent of the added organic carbon which evolved as CO_2 increased with an increase in temperature from 4° to 12°C. for all three successive loads and for the second and third successive loads from 12° to 20°C. The exception in this tendency was the first load, which gave rise to a lower proportion of carbon volatilized at 20°C. compared to 12°C. A major contributor to this phenomenon was the treatment receiving soil-excreta in the ratio of 10:2.5 which decomposed at a rather sluggish rate at the higher temperature.

Table 10

Percent of organic carbon added evolved as CO_2-C in the temperature, loading, and successive loads experiment

Temp. Deg.C	loading soil:	excreta	Number of successive loads	% organic carbon added evolved as CO_2-C Biometer 1	2	3	Avg.
4	10.0	0.0	1	15.7	15.1	14.9	15.2
			2	13.5	9.4	11.4	11.4
			3	74.0	63.9	69.6	69.1
	10.0	1.0	1	37.5	38.5	38.1	38.1
			2	44.6	49.6	45.8	46.7
			3	39.6	42.3	40.4	42.7
	10.0	2.5	1	28.2	28.3	28.2	28.2
			2	35.3	36.0	32.0	34.7
			3	28.3	28.6	24.8	27.2
12	10.0	0.0	1	35.3	35.6	36.1	35.7
			2	15.1	29.8	22.7	22.5
			3	79.8	70.4	71.4	73.9
	10.0	1.0	1	51.0	42.5	50.3	47.9
			2	49.4	39.0	49.6	46.0
			3	50.6	30.9	50.7	44.0
	10.0	2.5	1	44.7	45.4	47.8	46.0
			2	34.2	36.8	41.3	37.5
			3	30.2	29.9	29.9	30.0
20	10.0	0.0	1	22.0	15.8	14.8	17.5
			2	21.1	18.8	13.6	17.8
			3	85.6	76.9	73.2	78.6
	10.0	1.0	1	62.2	55.1	64.6	60.6
			2	67.7	50.0	66.8	61.5
			3	61.9	47.5	75.5	61.6
	10.0	2.5	1	29.0	48.0	25.1	34.0
			2	27.4	46.3	26.0	33.2
			3	28.7	33.8	36.3	32.8

Figure 11. Percent organic carbon added evolved as CO_2-C in the temperature, loading, and successive load experiment. Average of three biometers.

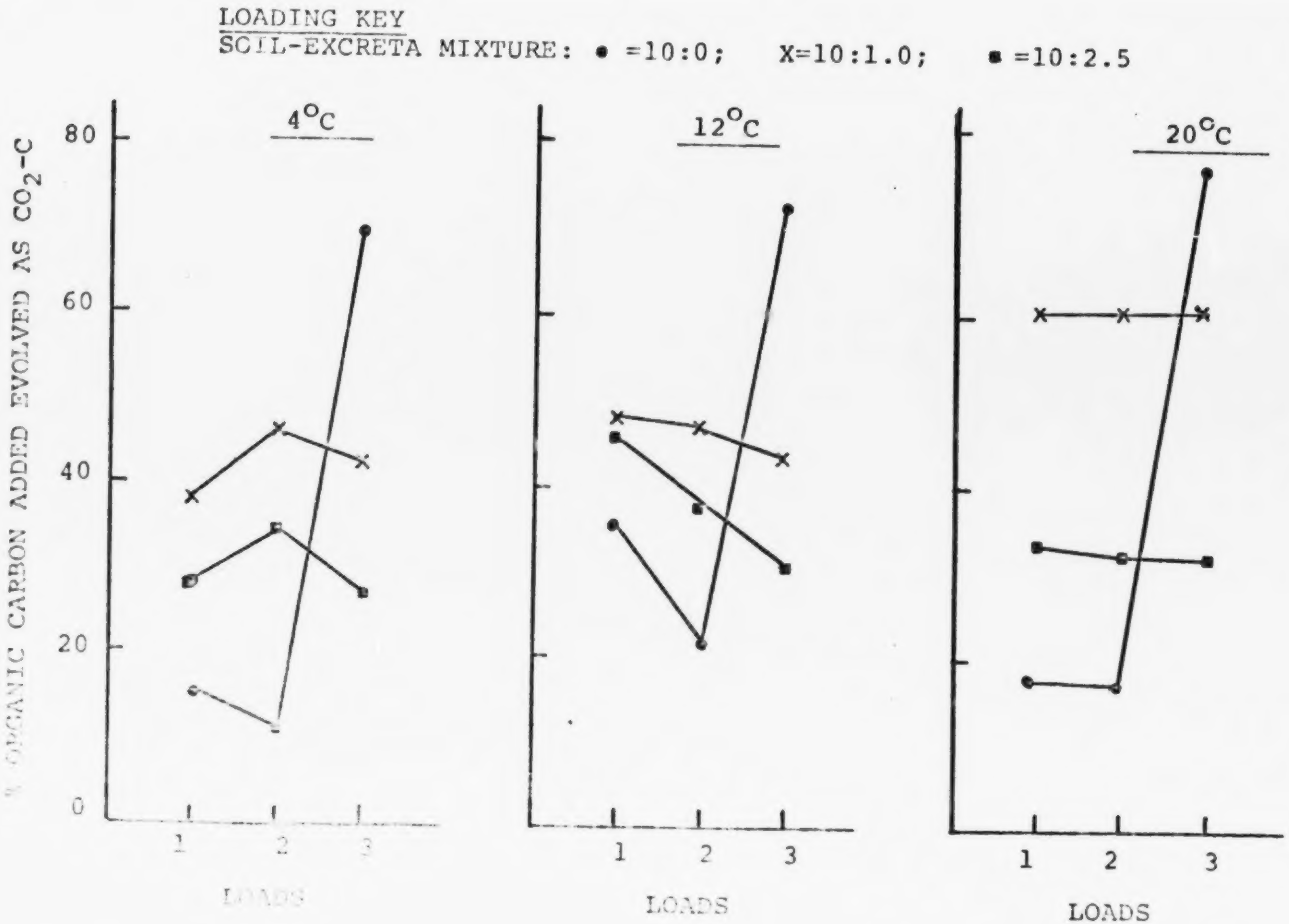


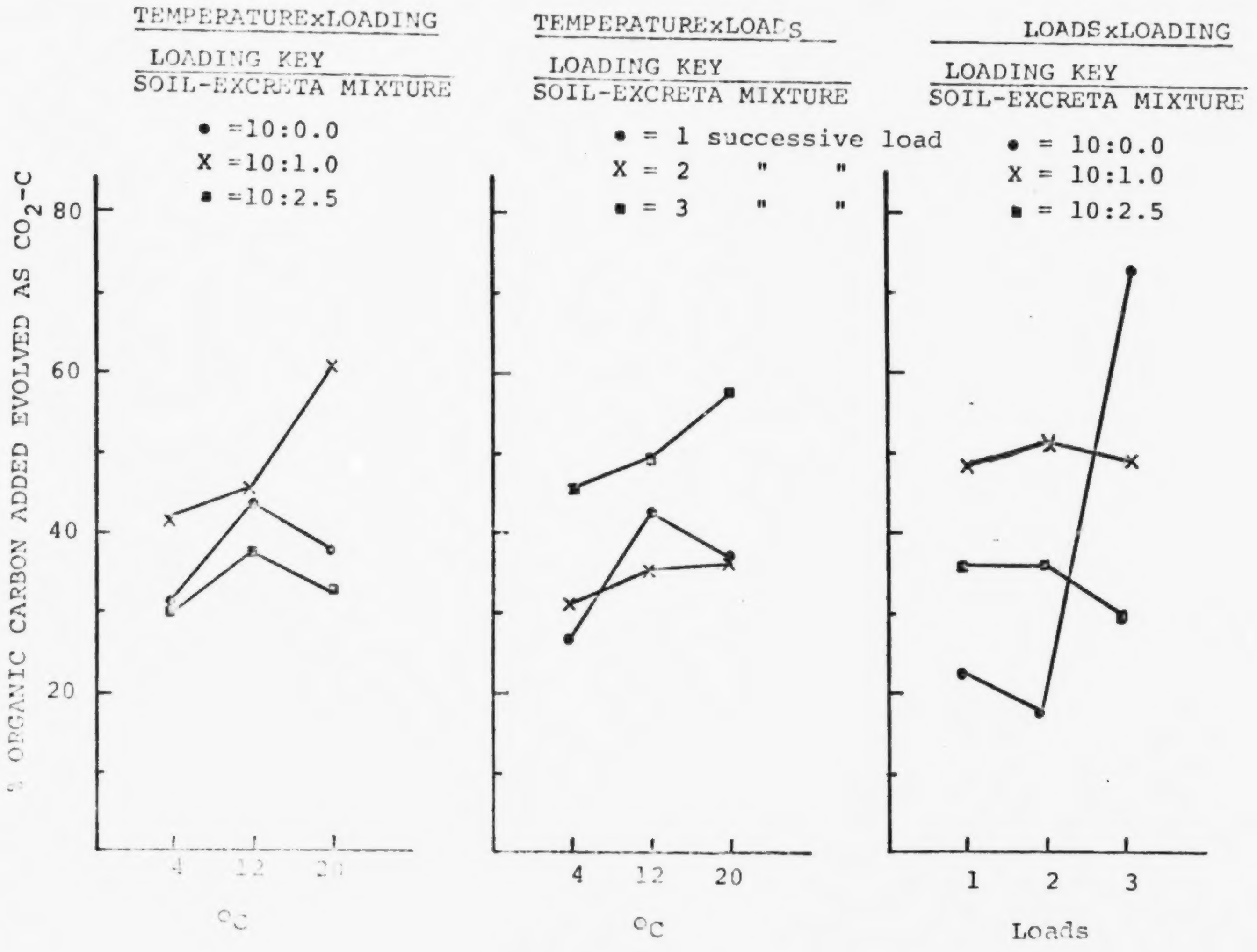
Table 11

ANOVA table for percent of organic carbon evolved as CO_2-C in the temperature, loading, and successive loads experiment

Variation	Degree of freedom	Sum of squares	Mean square	F calculated	F took[1,2]
Total	80	27086.86			
Temperature (T)	2	1429.24	714.62	8.48**	6.01[1]
Loading (L)	2	3652.33	1841.17	21.84**	6.01[1]
TxL	4	1382.28	345.47	4.10*	2.93[2]
Biometers in TxL	18	1517.72	84.32	5.91**	2.50[1]
Successive Load(s)	2	4437.53	2218.78	155.45**	5.26[1]
TxS	4	639.66	159.92	11.20**	3.91[1]
LxS	4	13312.75	3328.19	233.18**	3.91[1]
TxLxS	8	171.46	21.43	1.50	
Residual	36	513.85	14.27		

[1] 1.0% significance level
[2] 5.0% significance level
*differences were significant at the 5% probability level
**differences were significant at the 1% probability level

Figure 12. Significant interactions of percent organic carbon added evolved as CO_2-C in the temperature, loading, and successive loads experienced.



Loading x successive loads. Because both of these parameters can be controlled in the field, this is the interaction of greatest practical significance. The substantially more complete destruction of organic matter achieved at the lower loading ratio is clearly revealed in this interaction. Also revealed is the tendency towards a decline in the proportion of the added organic matter volatilized after addition of the third successive load at the higher loading ratio (10:2.5). The choice of application regimens clearly involves balancing the desirability of adding large amounts of waste at one time versus the more rapid decomposition achieved by smaller waste applications.

Ammonia evolution. Examination of Figures 13a, 13b, and 13c shows that NH_3 evolution follows a somewhat sigmoidal curve, especially at the lower incubation temperatures. As with CO_2, the absolute amount of NH_3 evolved was always greater with the 10:2.5 loading ratio than the 10:1 ratio. Additional interpretations depend on converting the data to the percent of the added nitrogen volatilized and statistical analysis.

Expressing the data on a percent basis (Figure 14) it can be seen that NH_3 evolution was usually more extensive at the lower loading ratio (10:1). Exceptions do exist however, at incubation temperatures of 12° and 20°C. In general, the proportion of nitrogen lost is less influenced by the loading than is the comparable loss of carbon.

The ANOVA for the NH_3 appears in Table 13; this indicates that the only two-way interaction which affected NH_3 evolution was loading x successive loads. This is further supported by the fact that in the main effects only loading and successive loads were of sufficient magnitude to be significant. Figure 15 is a graphic representation of the loading x successive loads interaction. The two loading ratios behave similarly; at both loadings there was little change in the proportion of nitrogen evolved between the first and second loads.

Nutrient concentrations. The pH concentrations of selected nutrients were determined at the termination of the experiment (Table 14). The pH rose with incubation of soil-excreta mixtures, a maximum value of 8.6 being noted. In general, the addition of excreta resulted in the mineralization of trace elements (iron, zinc, copper and manganese) whereas large amounts of major elements (magnesium, phosphorus, potassium, and calcium) were released into soluble form.

Figure 13a. Cumulative NH_3-N evolved by various soil-excreta mixtures receiving three successive loads and incubated at 4 °C. Average of three biometers.

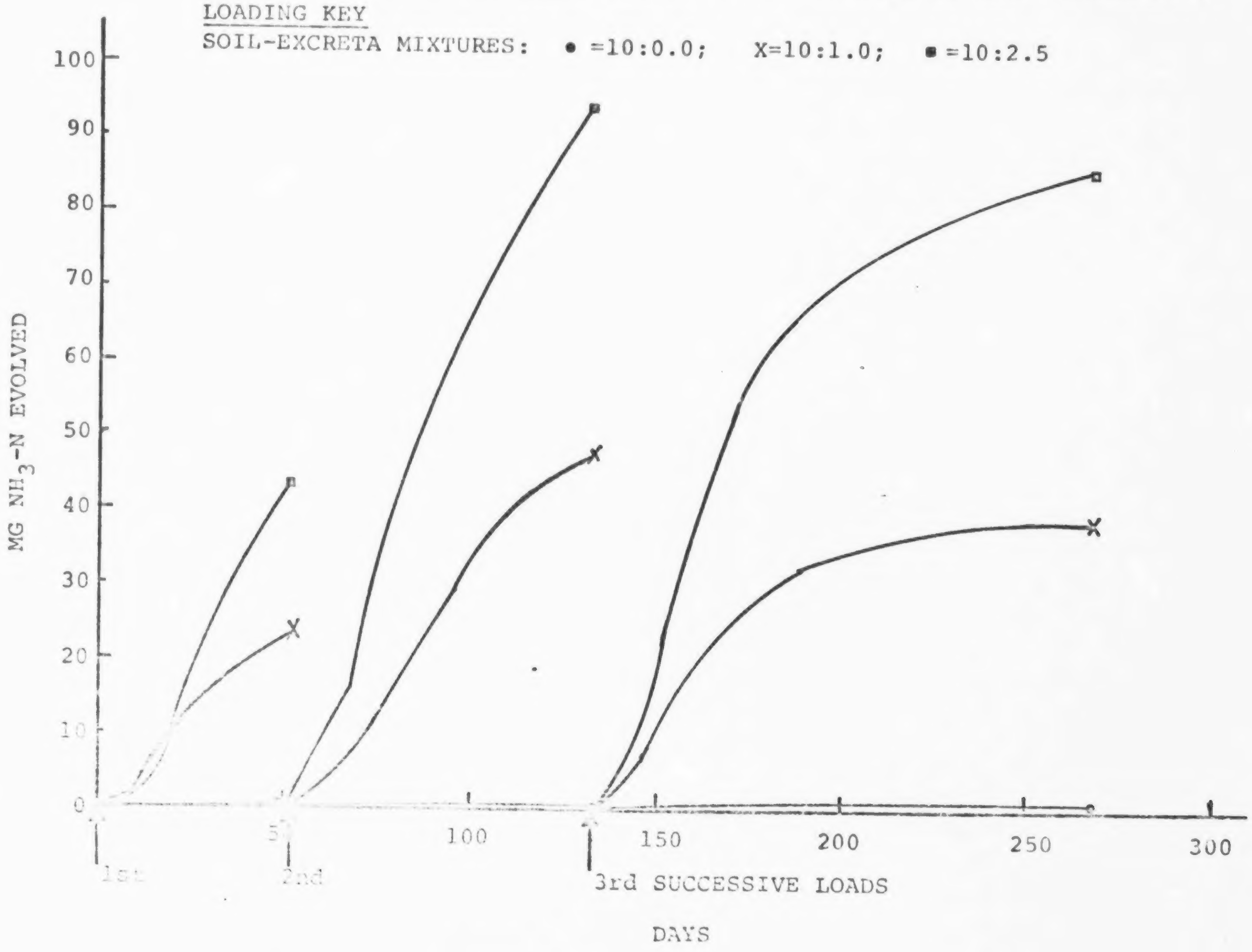


Figure 13b. Cumulative NH_3-N evolved by various soil-excreta mixtures receiving three successive loads and incubated at 12°C. Average of three biometers.

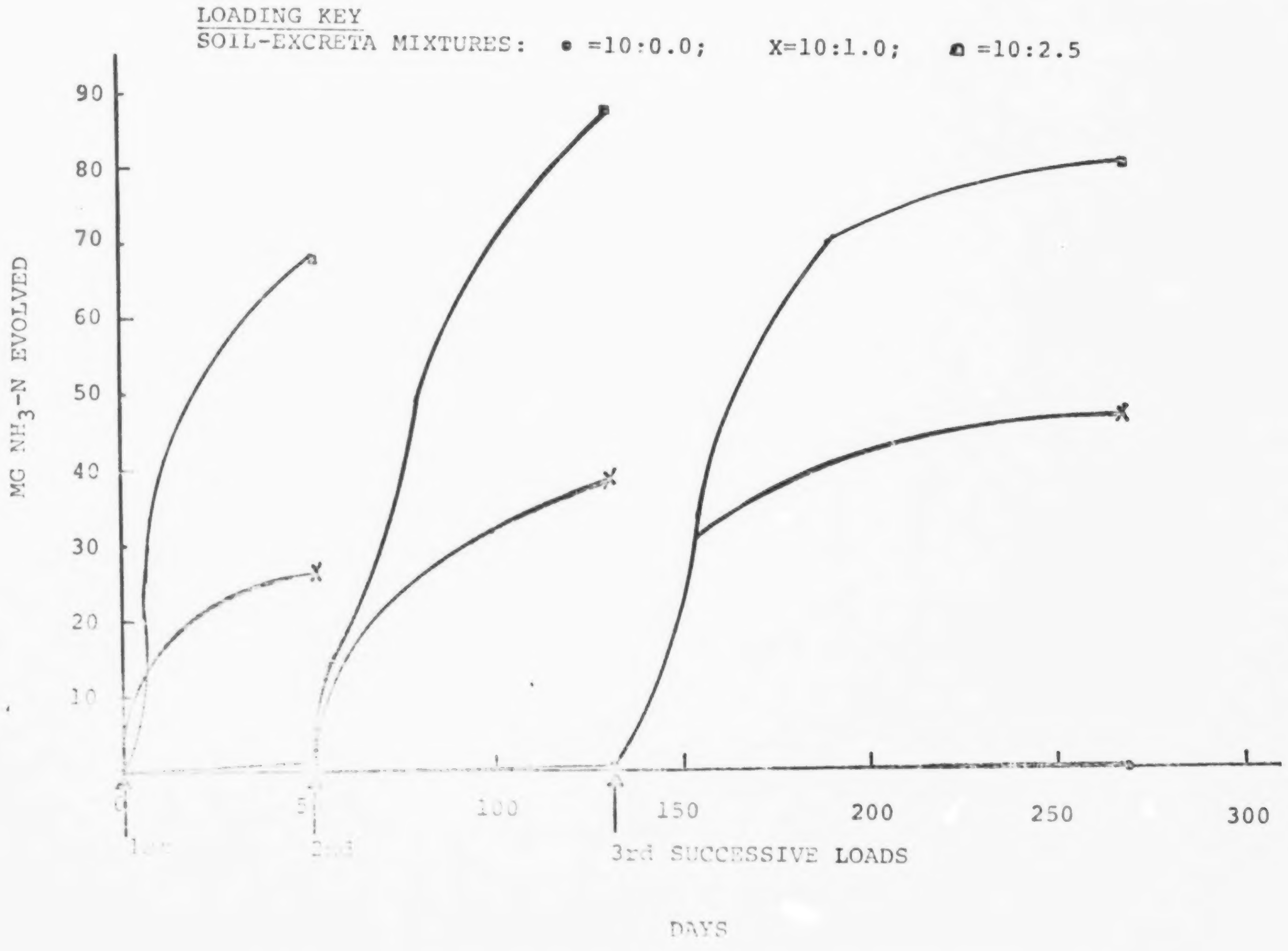


Figure 13c. Cumulative NH_3-N evolved by various soil-excreta mixtures receiving three successive loads and incubated at 20°C. Average of three biometers.

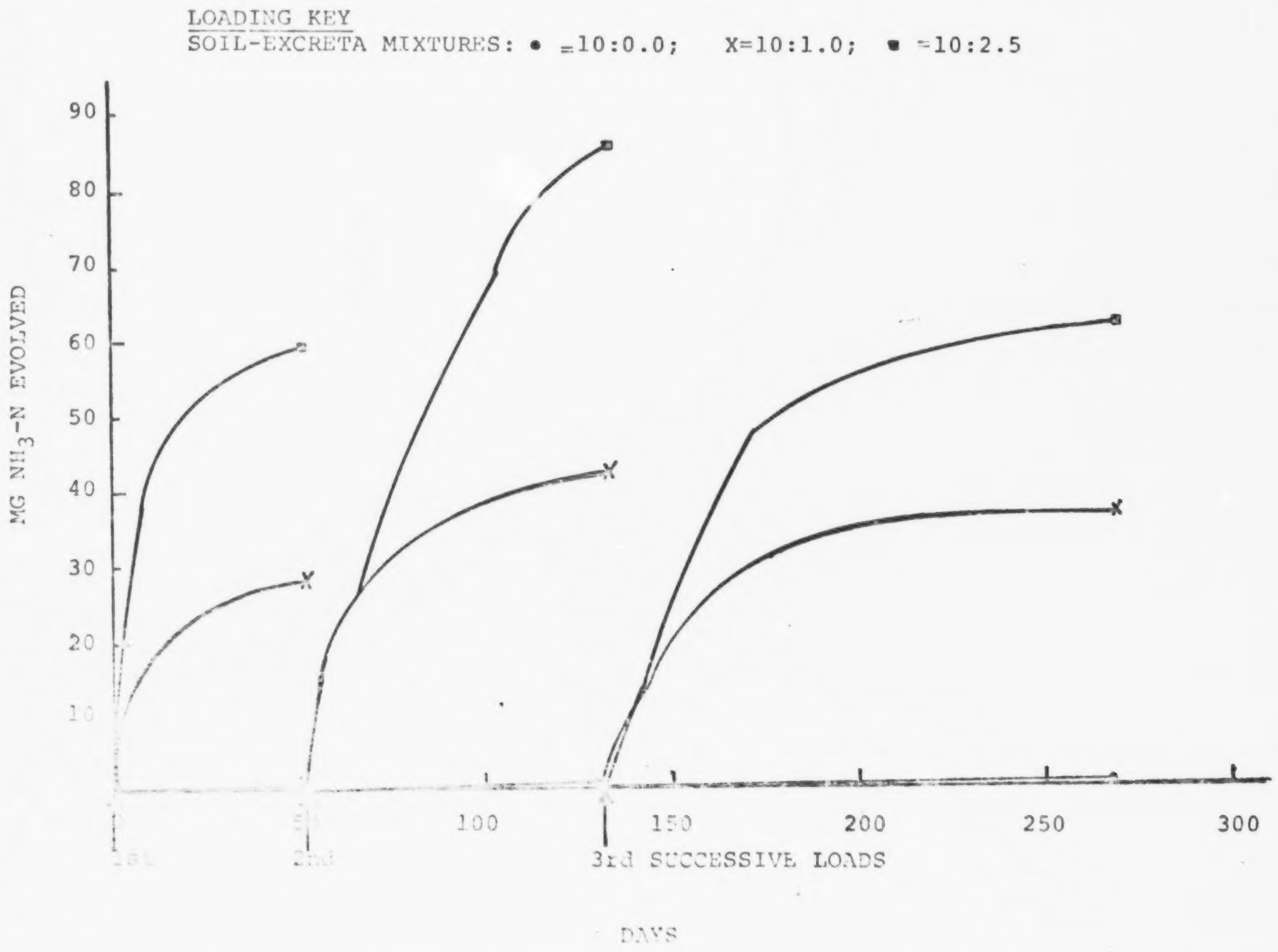


Figure 14. Percent of nitrogen added evolved as NH_3-N in the temperature, loading, and successive loads experiments. Average of three biometers.

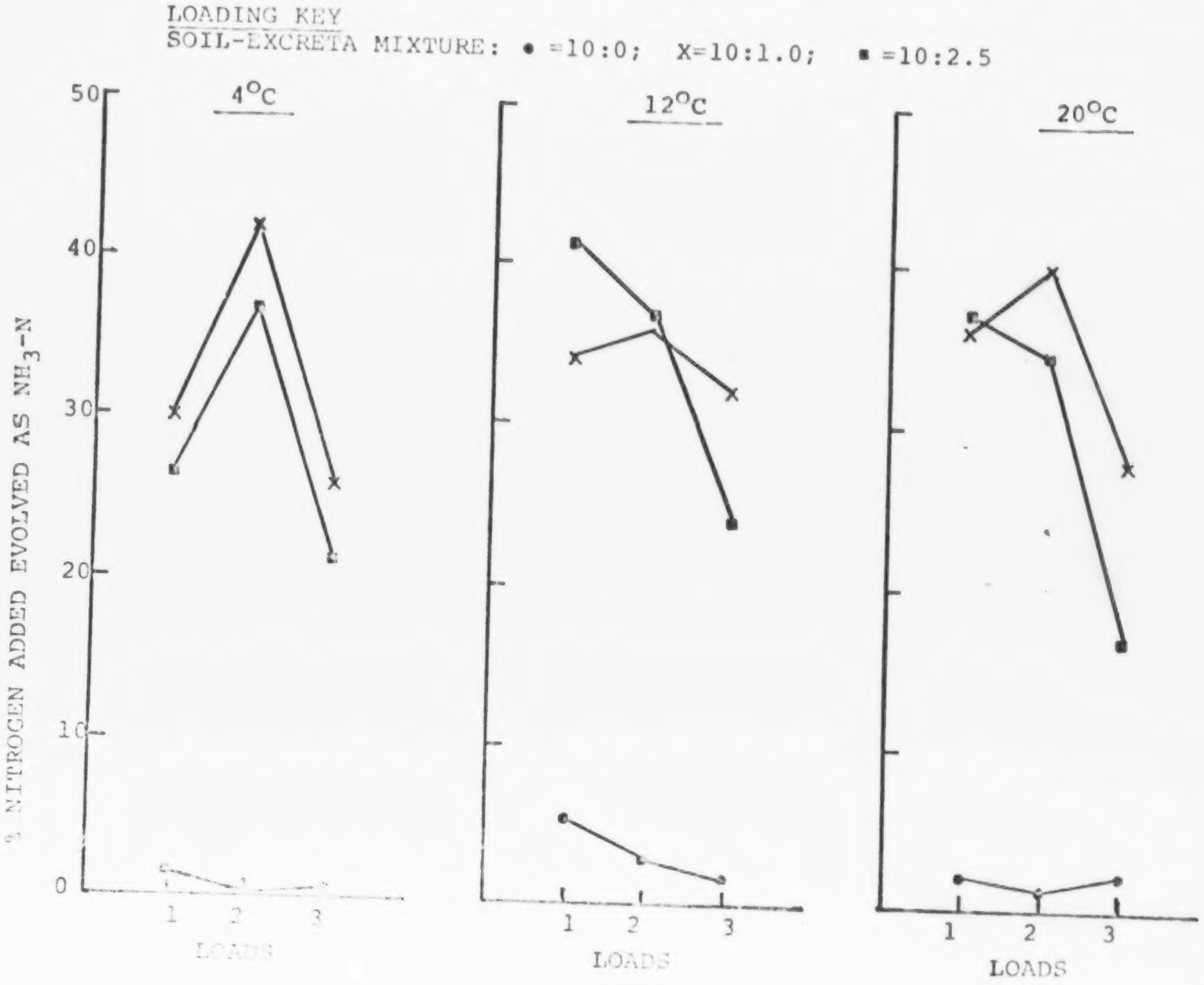


Table 13

ANCVA table for percent nitrogen added evolved as NH_3-N in the temperature, loading, and successive loadings experiment

Variation	Degree of freedom	Sum of squares	Mean squares	F calculated	F look[1]
Total	80	20633.48			
Temperature (T)	2	139.53	69.77	2.24	
Loading (L)	2	16605.17	8302.08	267.12**	6.01
TxL	4	75.80	18.95	0.61	
Biometers in TxL	18	559.36	31.08	1.08	
Successive loading(s)	2	1099.24	549.62	19.17**	5.26
TxS	4	223.89	55.97	1.95	
LxS	4	719.63	179.91	6.28**	3.91
TxLxS	8	209.59	26.20	0.91	
Residual	36	1032.23	28.67		

[1] 1.0% significance level

**differences were significant at the 1% probability level.

Figure 15. Significant loading x loads interaction for the percent nitrogen added evolved as NH_3-N.

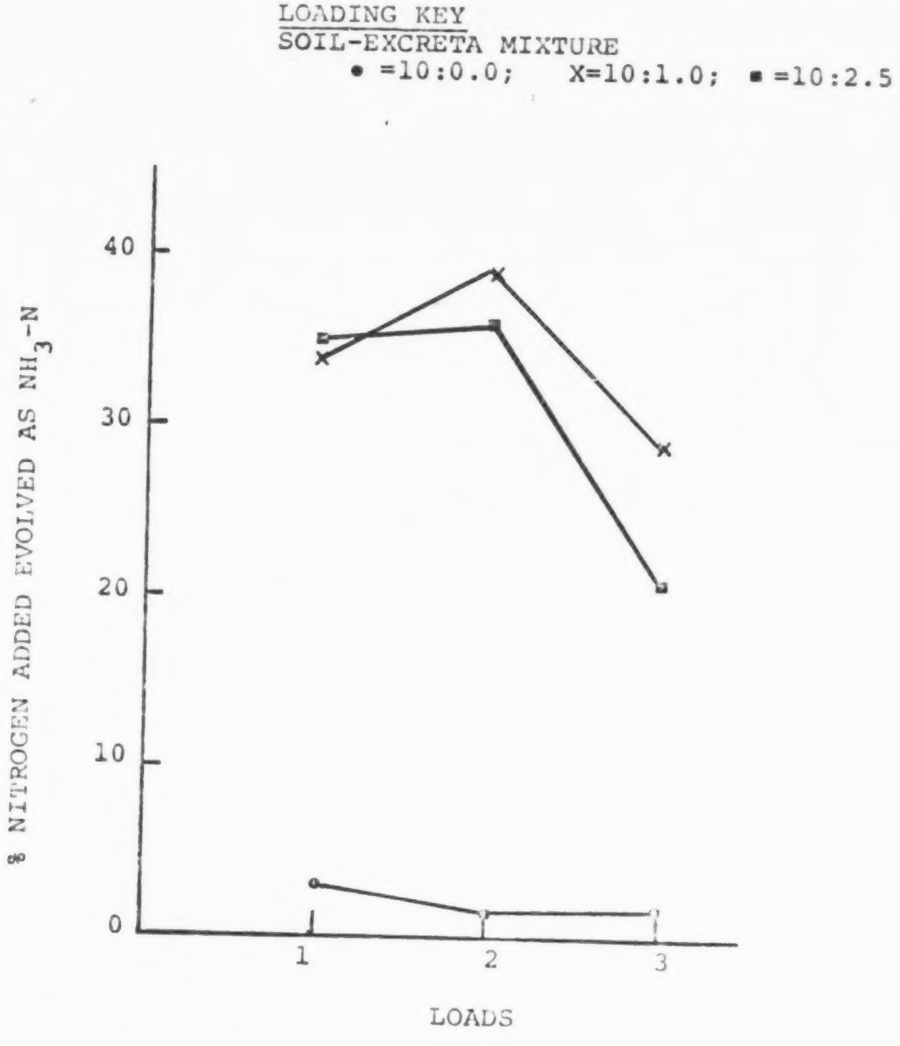


Table 14

The final pH and concentrations of selected nutrients after completion of the temperature, loading and successive loads experiment

Temp.	Loading soil:excreta	pH	Iron	Zinc	Copper	Manganese	Magnesium	Phosphorus	Potassium	Calcium
4°C	10:0	6.3	75	30	8.0	18.0	333	210	567	840
	10:1.0	7.8	5	20	2.2	22.0	770	1442	3008	3478
	10:2.5	8.4	5	16	1.4	12.0	889	1617	4788	3026
12°C	10:0	6.3	60	25	7.5	18.0	322	154	525	784
	10:1.0	8.0	14	18	0.8	15.2	672	1232	2562	3248
	10:2.5	8.6	11	12	1.4	6.4	924	1624	5460	3248
20°C	10:0	6.3	46	20	5.6	26.0	406	189	578	784
	10:1.0	8.3	trace	20	1.0	11.6	767	1302	3308	3248
	10:2.5	8.3	5	20	1.6	14.0	1050	1316	5334	4032

Effect of Soil Texture on Excreta Decomposition

Light, medium, and heavy textured soils were used to study the effect of soil texture on decomposition. The soils used were Cologne loamy sand, Adelphia sandy loam, and Flanders loam; soil-excreta ratios were 10:0, 10:1, and 10:2.5. Incubation was at 12°C. Only CO_2 was monitored.

The results, expressed as the absolute amount of CO_2 evolved (Figures 16a, 16b, and 16c), indicate that the lightest soil (loamy sand) supported the most intense decomposition at the 10:2.5 soil-excreta loading ratio. At the lower loading ratio, there appears to be little difference among soils.

Data for days 61, 98, and 288 were converted to a percent basis (percent of added organic carbon recovered as CO_2) and plotted in Figure 17. In all soils and at all three times, the extent of decomposition was substantially greater at the 10:1 loading compared to the 10:2.5 loading.

Several ANOVA's were computed from the data, the first on data for 61 days (Table 15). The only variable exhibiting a significant effect is loading. The loading response was similar for all three soils, and the maximum response was at the 10:1 soil-excreta loading ratio. This effect was most pronounced with the loam soil. At the 10:2.5 loading, decomposition was not retarded as much in loamy sand, compared to the heavier soils.

A second ANOVA was calculated for the data for 61, 98, and 288 days incubation (Table 16). As would be expected, the amount of CO_2-C evolved was significantly different with length of incubation period. The data for the main effect days incubated is presented in Table 18. Of interest is the slight (3.5%) increase in percent organic carbon volatilized when the incubation period is extended from 61 to 98 days. With an additional 190 days incubation a further 7 percent of the organic carbon is released as CO_2. The most intensive activity clearly occurs at the earlier stages of incubation.

The greatest proportion of added organic material was volatilized in the loamy sand (Table 19), where some 37 percent was recovered as CO_2. In the heavier soils, from 27-30 percent recovery was noted, however, those differences were not statistically significant.

As in previous experiments, the greatest percent volatilization occurred at the 10:1 loading ratio (Tabl3 20). In 288 days, 44 percent of the added organic carbon was volatilized as compared to 25 percent at the higher loading ratio (10:2.5).

The biometers in SxL data provides an insight into the variability which develops with lime. At 60 days incubation there were no apparent differences between biometers, but at 288 days there were significant differences.

Figure 16a. Cumulative CO_2-C evolved by loamy sand with various soil-excreta mixtures incubated at 12°C. - Average of two biometers.

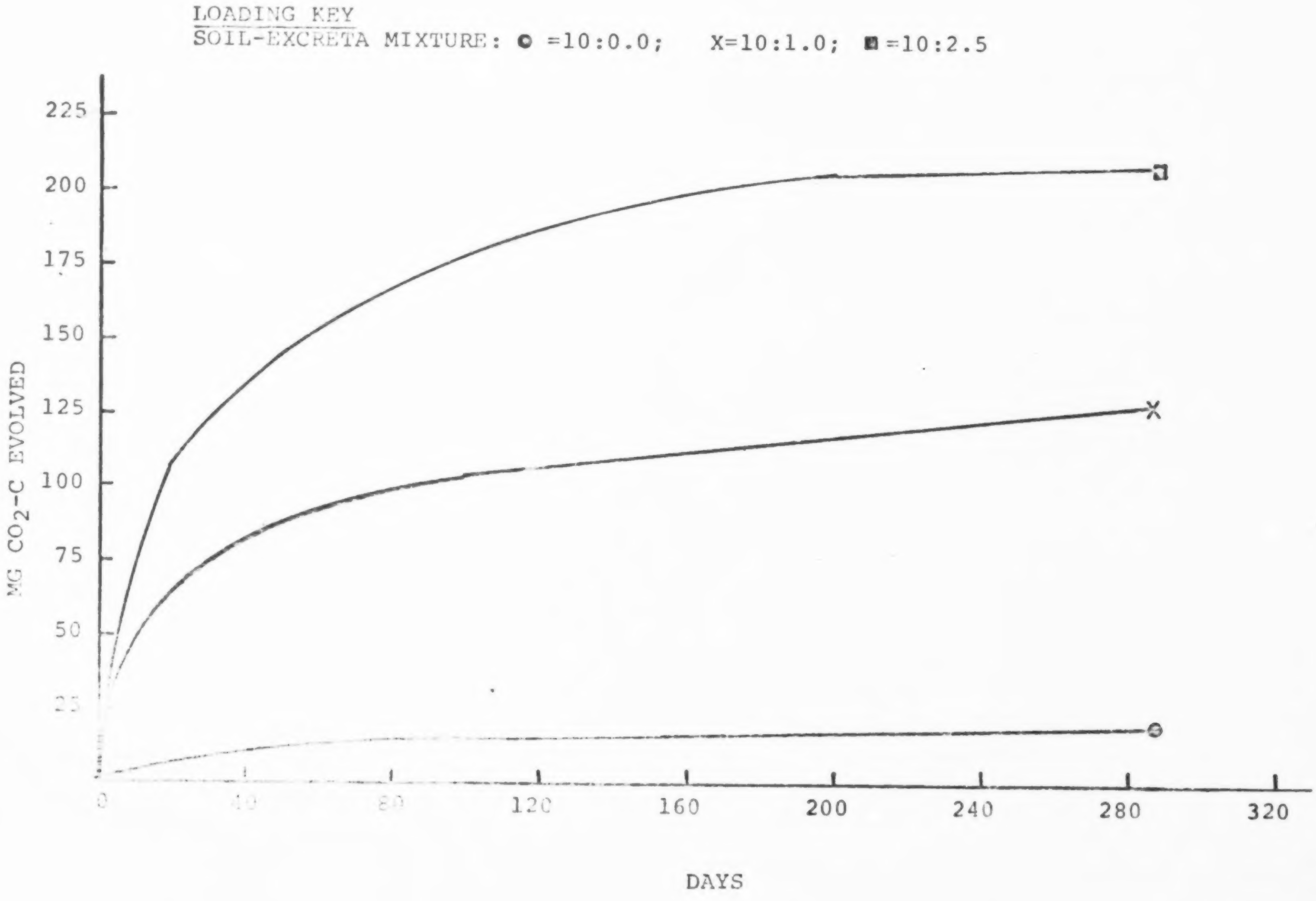


Figure 16b. Cumulative CO_2-C evolved by sandy loam with various soil-excreta mixtures incubated at 12°C. Average of two biometers.

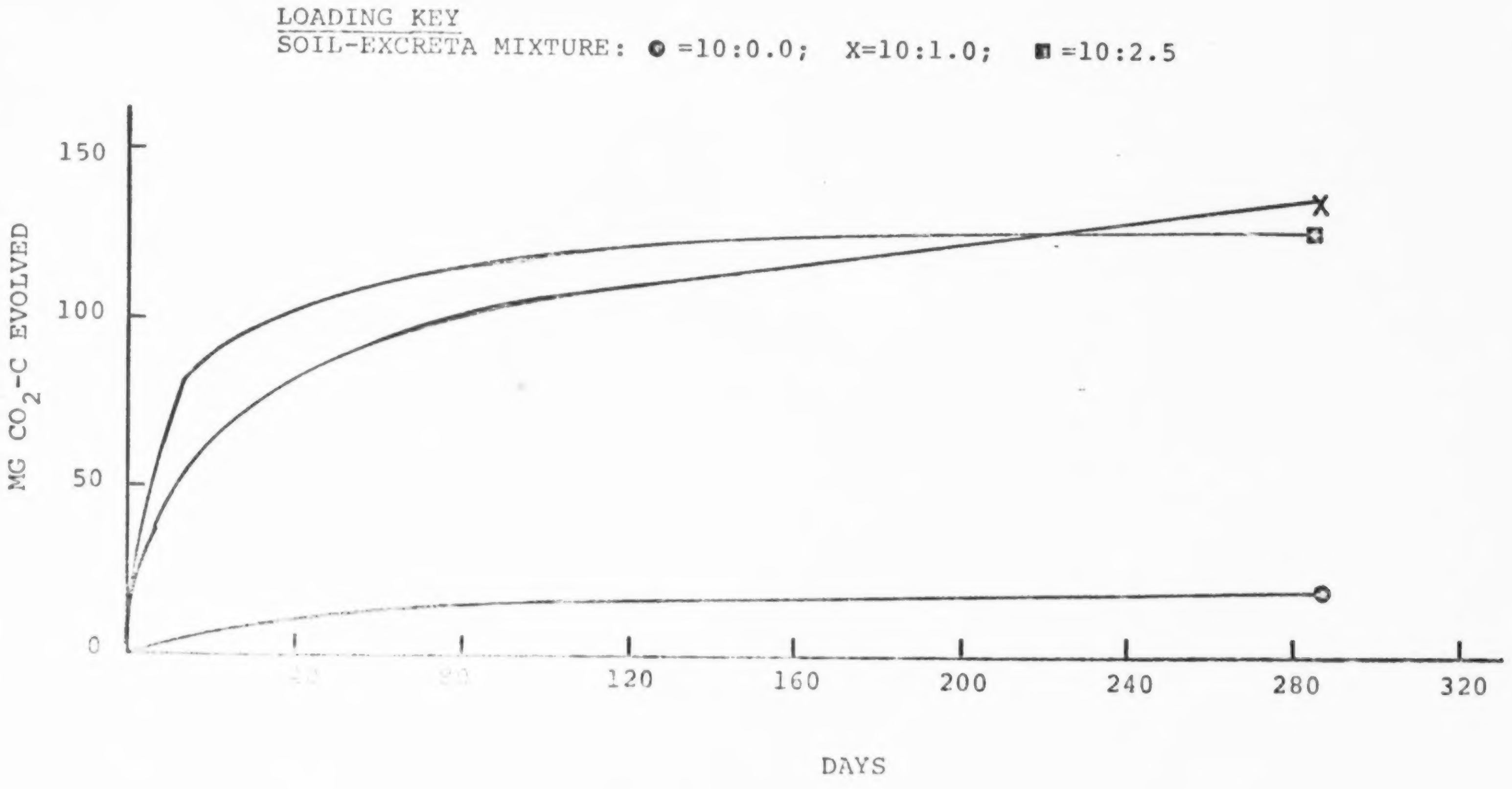


Figure 16c. Cumulative CO_2-C evolved by loam with various soil-excreta mixtures incubated at 12°C. Average of two biometers.

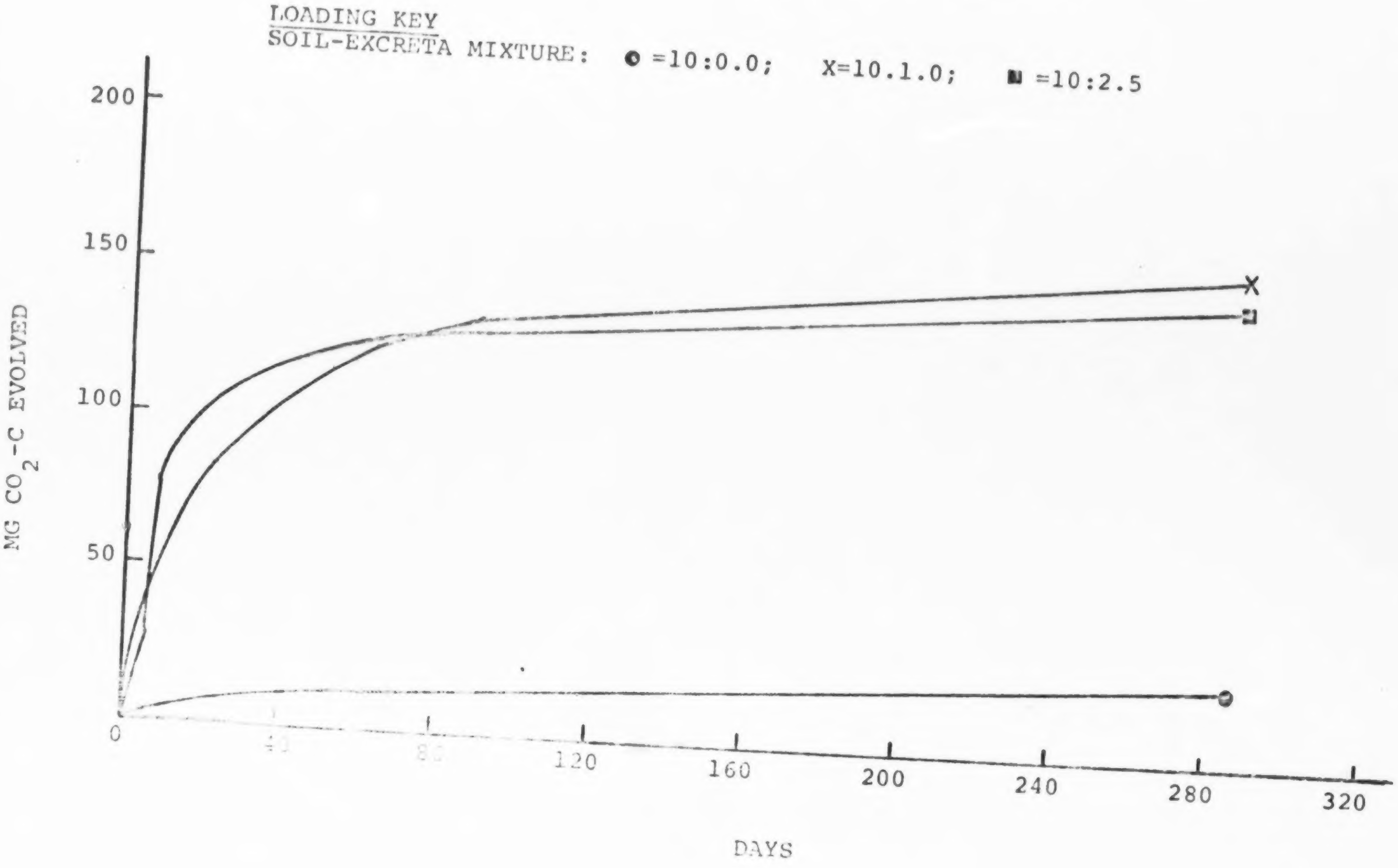


Figure 17. Percent organic carbon added evolved as CO_2-C by various soil textures and soil-excreta mixtures incubated at 12°C. Average of two biometers.

INCUBATION KEY: ● =60.8 days; X=97.8 days; ■ =287.8 days

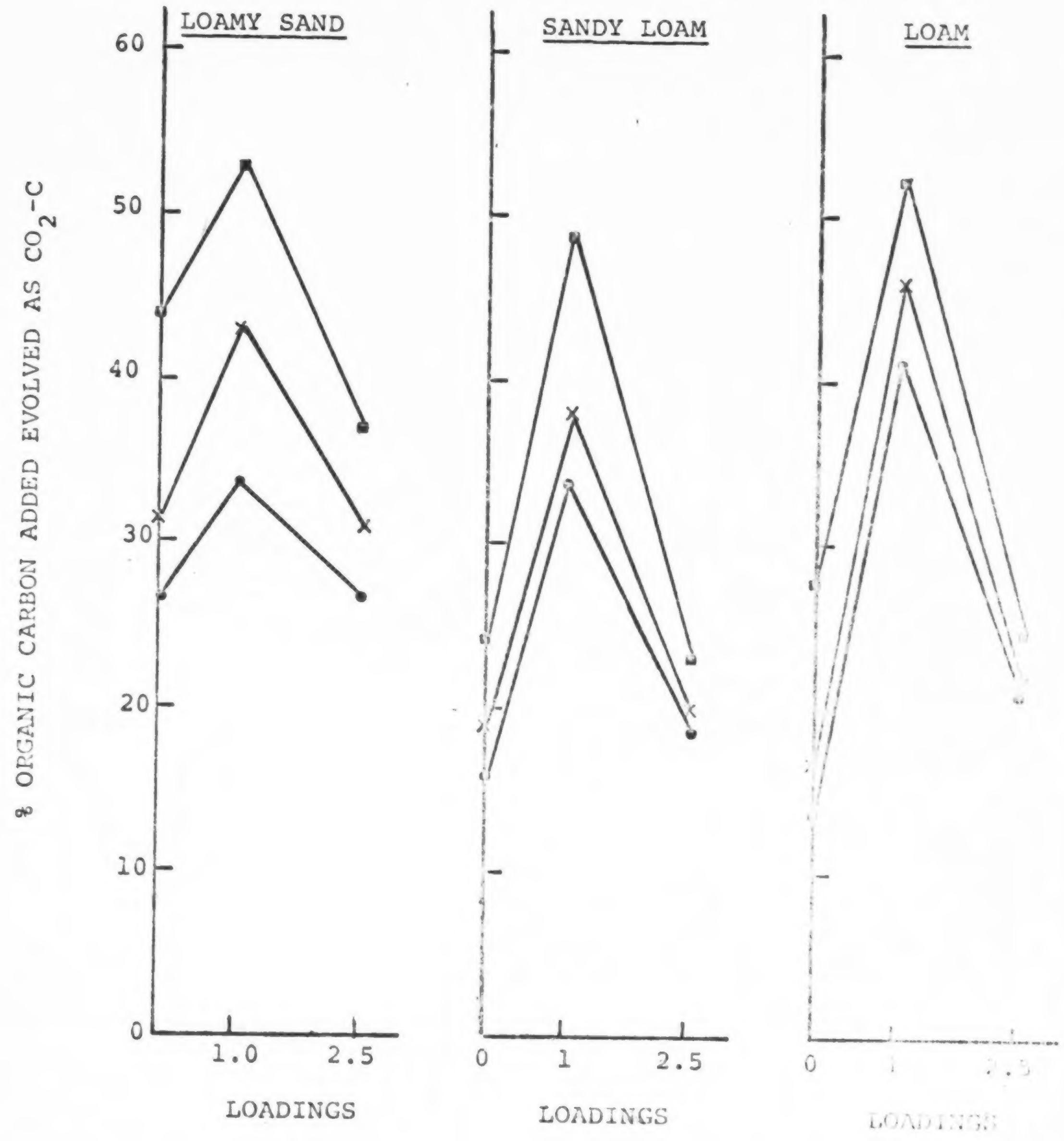


Table 15

ANOVA table for percent carbon added evolved as CO_2-C in the soil texture and loading experiment after 6 days incubation

Variation	Degree of freedom	Sum of squares	Mean squares	F calculated	F book[1]
Total	17	1811.68			
Soil texture (S)	2	191.61	95.80	4.26	
Loading (L)	2	1291.21	645.60	28.71**	8.02
SxL	4	126.49	31.62	1.41	
Residual	9	202.37	22.49		

[1] 1.0% significance level.

**Differences were significant at the 1% probability level

Table 16

ANOVA table for percent carbon added evolved as CO_2-C in the soil texture and loading experiment over various incubation periods

Variation	Degree of freedom	Sum of squares	Mean squares	F calculated	F book[1]
Total	53	8750.92			
Soil texture (S)	2	982.97	491.49	3.34	
Loading (L)	2	4494.08	2247.04	15.28**	8.02
SxL	4	409.21	102.30	0.70	
Biometers in SxL	9	1323.11	147.01	15.32**	3.60
Days incubated (D)	2	1157.33	578.67	60.29**	6.01
SxD	4	47.07	11.77	1.23	
LxD	4	117.12	29.28	3.05	
SxLxD	8	47.27	5.91	0.62	
Residual	18	172.76	9.60		

[1] 1.0% significance level

**Differences were significant at the 1% probability level

Table 18

Percent organic carbon added evolved as CO_2-C for days incubated at 20°C in the soil texture, loading and incubation period experiment

Days incubated	% TOC added evolved as CO_2-C
60.8	26.2
97.8	29.8
287.8	37.2

Table 19

Percent organic carbon added evolved as CO_2-C for soil textures in the soil texture, loading, and incubation period experiments

Soil texture	% TOC added evolved as CO_2-C
loamy sand	36.9
sandy loam	26.8
loam	29.5

Table 20

Percent organic carbon added evolved as CO_2-C for loadings in the soil texture, loading, and incubation period experiment

Loadings grams of Droppings[1]	Soil[1]	% TOC added evolved as CO_2-C
0.0	10.0	24.2
1.0	10.0	43.9
2.5	10.0	24.8

[1] Air dried weight basis

Effect of Salts on Decomposition

The salts contained within chicken excreta would be released upon complete decomposition and possibly accumulate in the soil. Development of high salt concentrations could retard decomposition, thus adversely affecting the use of soil as a disposal medium. Accordingly, a factorial experimental design was used to test the effects of the variables, salt addition, loading, and biometer replication, on the decomposition of excreta incorporated into soil. Adelphia sandy loam was combined with excreta in ratios of 10:0, 10:1, and 10:2.5. The salt concentrations used were based on the concentrations found in excreta as reported in Table 6, except that nitrogen was not included. The salts added were equivalent to that contained in 0, 3, 6, 9, and 12 excreta loads where the soil-excreta loading was at 10:1, salts additions were based on that loading, similarly, when the soil-excreta loading was 10:2.5, the salt additions were based on the higher loading. The evolution of CO_2 and NH_3 was monitored; incubation was at 20°C.

The results expressed as the cumulative evolution of CO_2 are presented in Figure 18, and as the percent of the organic carbon added which was volatilized in Figure 19. As with previous experiments, substantially more of the added organic carbon was volatilized at the lower loading ratio. This ratio, however, appears to be more sensitive to the effects of salts than the 10:2.5 ratio.

An ANOVA of the percent organic carbon evolved as CO_2 (Table 21) indicates that only the main effects, loading and salt concentrations were significant. Figure 20 shows that maximum carbon is evolved by the 10:1 loading as in previous experiments. The effect of all salt additions was to lower the percent organic carbon volatilized, however, the salts equivalent to 3 previous loads only slightly inhibited volatilization (Figure 20).

The cumulative NH_3-N results appear in Figure 21. The NH_3-N evolution pattern is unlike that for CO_2-C. Figure 21 clearly shows that all levels of salt additions stimulated NH_3-N evolution at the 10:1 loading, likewise all levels of salt addition except the highest stimulated NH_3-N volatilization at the 10:2.5 loading.

An ANOVA (Table 22) of the percent nitrogen added evolved as NH_3-N indicated that loading was the only statistically significant effect. An examination of the interaction indicates that only at the highest loading and salt concentration was there a noticeable inhibition of nitrogen volatilization.

In summary, NH_3 evolution was favored by the higher salt concentrations which might result from many additions of excreta and the CO_2 evolution was inhibited by similar salt levels.

Figure 18. Cumulative CO_2-C evolved by various soil-excreta mixtures receiving five levels of salt additions incubated at 20°C. Average of two biometers.

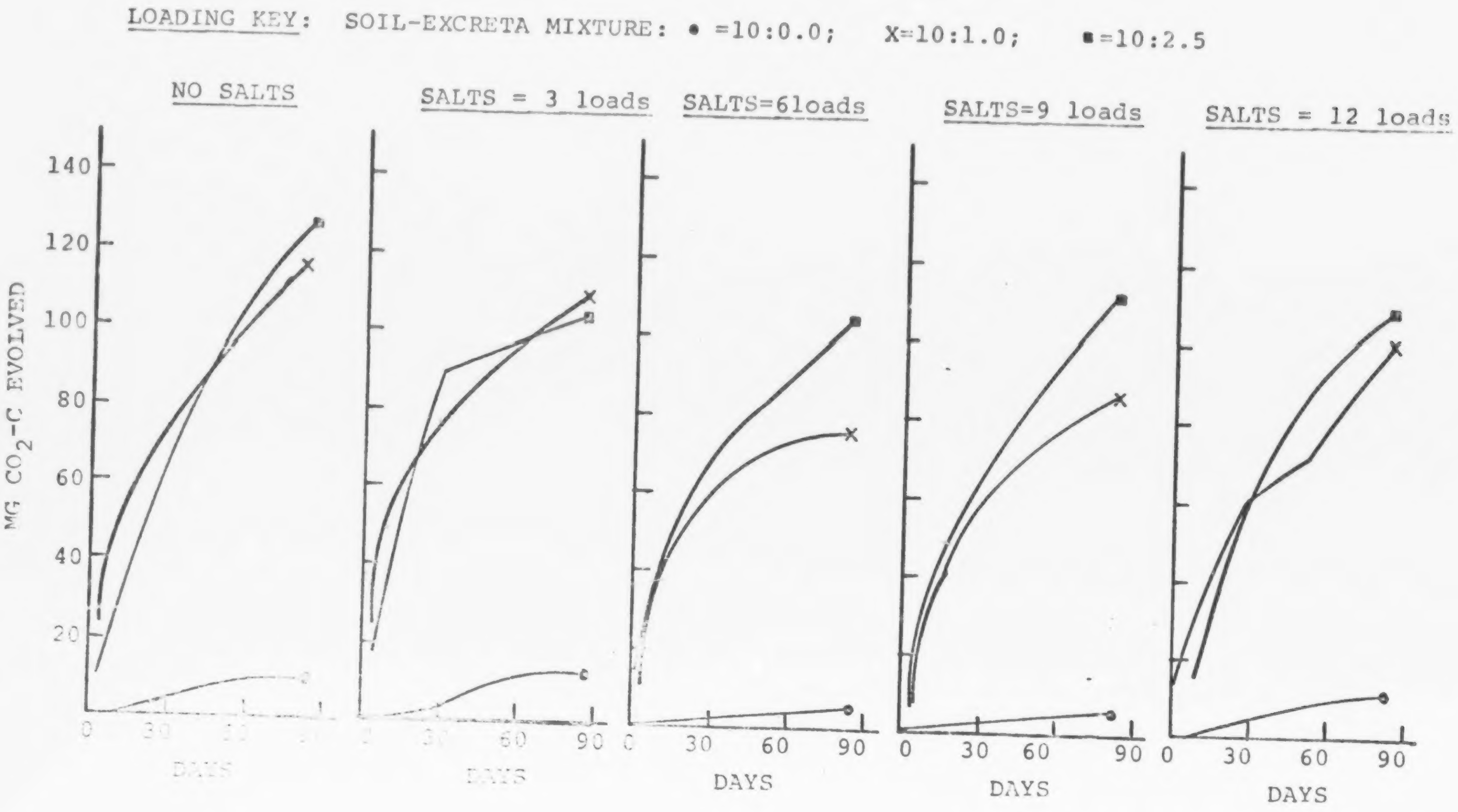


Figure 19. Percent organic carbon added evolved as CO_2-C by various soil-excreta mixtures receiving five levels of salt additions incubated at 20°C. Average of two biometers.

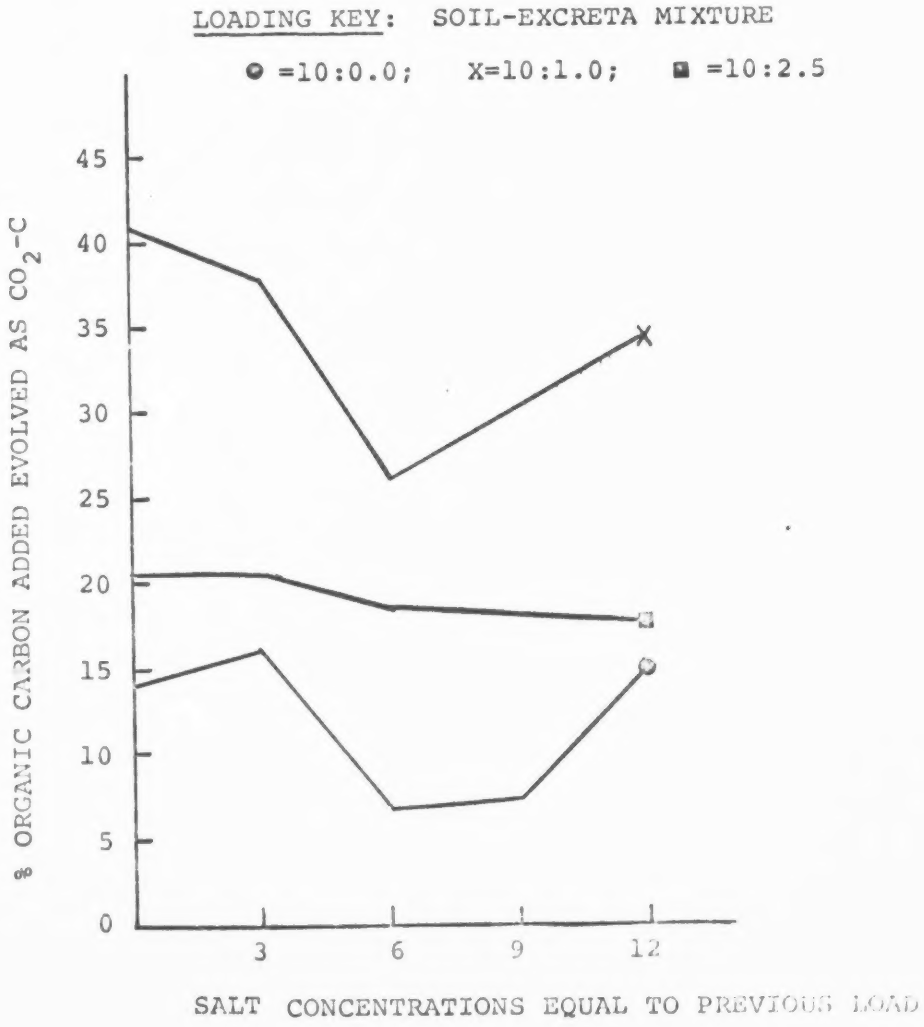


Table 21

ANOVA table for percent organic carbon added evolved as CO_2-C by droppings-soil mixtures at three loadings receiving salt additions at five levels and incubated at 83.9 days at 20°C

Variation	Degree of freedom	Sum of squares	Mean square	F calculated	F book[1,2]
Total	29	3163.01			
Loading (L)	2	2516.20	1258.1	107.59**	99.4[1]
Salt (S)	4	311.90	77.98	6.67*	5.86[2]
LxS	8	129.51	16.19	1.38	
Residual	15	175.40	11.69		

[1] 1.0% significance levels
[2] 5.0% significance levels
**Differences were significant at the 1% probability level

Figure 20. Significant main effects in percent organic carbon added evolved as CO_2-C in the various soil-excreta mixtures receiving different levels of salt additions.

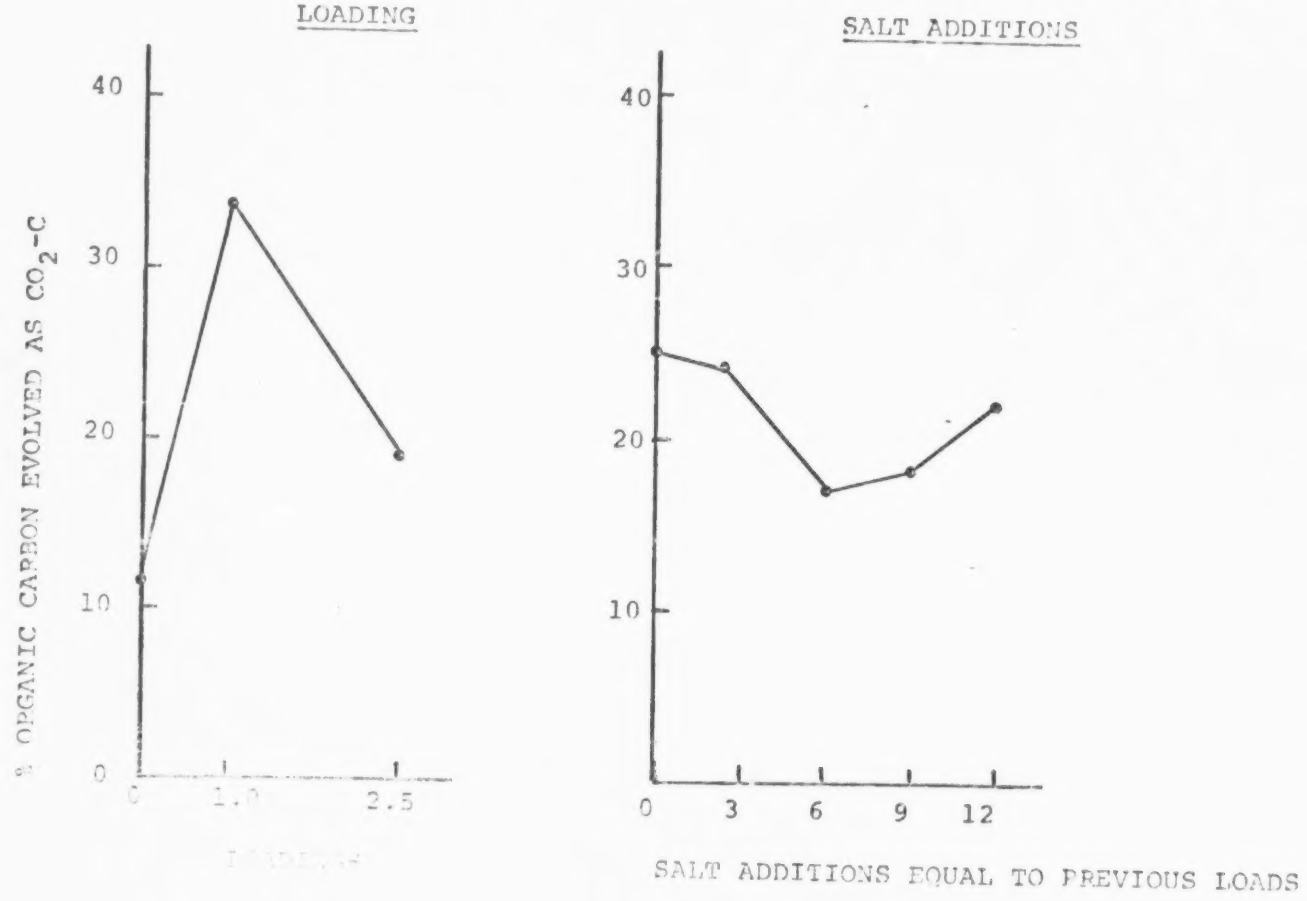


Figure 21. Accumulative NH_3-N evolved by various soil-excreta mixtures receiving five levels of salt additions incubated at 20°C. Average of two biometers.

LOADING KEY: SOIL-EXCRETA MIXTURE: ○ =10:0.0; X=10:1.0; ■=10:2.5.

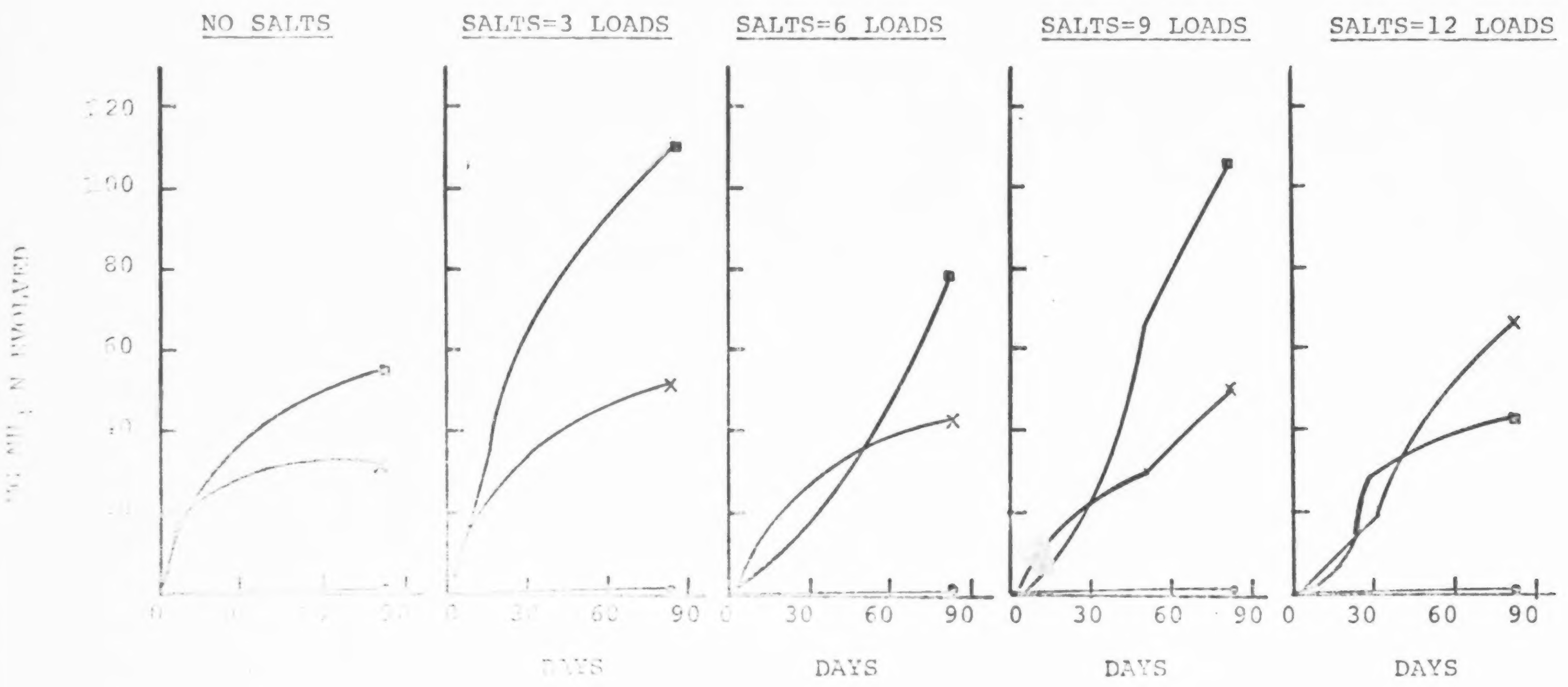


Table 22

ANOVA table for percent nitrogen added evolved as NH_3-N by dropping soil mixture at three loadings receiving salt additions at five levels and incubated at 83.9 days at 20°C

Variation	Degree of freedom	Sum of square	Mean square	F calculated	F book[1]
Total	29	24249.67			
Loading (L)	2	19748.09	9874.04	119.40**	99.4[1]
Salt (S)	4	1366.39	341.60	4.13	
LxS	8	1894.72	236.84	2.86	
Residual	15	1240.47	82.70		

[1] 1.0% significance level

**Differences were significant at the 1% probability level

Summary and Conclusions

Preliminary experimentation

1. The biometer apparatus is applicable to laboratory studies on the decomposition of chicken excreta in soil. Both CO_2 and NH_3 evolution can be monitored simultaneously by use of double sidearm biometers.

Effect of excreta loading on decomposition

1. The absolute amount of CO_2 evolved with a 10:10 soil-excreta loading ratio was three-fold greater than with a 10:1 ratio.
2. The absolute amount of NH_3 evolved with a 10:10 soil-excreta loading ratio was six-fold greater than with a 10:1 ratio.
3. The percent of organic carbon volatilized as CO_2 was greatest at the lower ratios. This amounted to about 56 percent during a 20-day period at ratios of 10:1 and 10:2.
4. The percent of organic nitrogen volatilized as NH_3 was greatest at the lower ratios. This amounted to 40 percent during a 20-day period at a ratio of 10:2.
5. Ammonia evolution, expressed on a percent basis, was less inhibited at the higher soil-excreta loading ratios than CO_2 evolution.

Effect of excreta loading, temperature, and successive excreta loads on decomposition

1. The following two-way interactions significantly influenced the extent of decomposition, as measured by CO_2 evolution:

   A. temperature x successive loads

   B. loading x successive loads

Temperature x successive loads

A three-fold increase in the rates of decomposition might have been expected over the temperature range of 4 to 20°C, based on the usual observation that biological activity increases roughly two-fold for a 10°C rise in temperature. In fact, temperature had substantially less influence than predicted on this basis. This indicates that the soil-excreta loading ratio, and the addition of successive loads of excreta, exerted a greater influence on decomposition than did temperature.

Loading x successive loads

The third successive load decomposed somewhat more slowly than the previous loads. The decline at the 10:2.5 loading was more severe than at 10:1. The third load, especially at the higher loading, therefore appears to have taxed the soil capacity to serve as a disposal medium.

Judged on the basis of NH_3 evolution, the loading x successive loads interaction was significant. At both soil-excreta loading ratios, NH_3 evolution declined substantially after the third load was added.

Nutrient concentrations and pH

1. Trace elements were immobilized and major elements solubilized, during the decomposition of excreta in soil.
2. The pH of the soil-excreta mixture tended to rise during incubation, reaching a maximum value of 8.6.

Effect of soil texture on excreta decomposition

1. During a 61-day incubation period using soils of differing texture, only loading significantly influenced the extent of decomposition. Soil texture did not significantly influence decomposition.

Effect of salts on decomposition

1. Ammonia volatilization from decomposing chicken excreta was stimulated by the presence of salts simulating the salt accumulation from previous loads of excreta. Conversely, the volatilization of CO_2 was suppressed by salts, but not severely.

General Comments

The laboratory respirometer studies emphasize the large number of options available, with regard to loading parameters, in the use of the Plow-Furrow-Cover method of disposal. In deciding on a regimen to use in field practice, the amount of land available, the amount of excreta requiring disposal, and the value of time spent on the disposal phase of the poultry operation must be considered.

High loading rates are advantageous in requiring a minimum of time for waste disposal operations. The disadvantage of incorporating very large amounts of excreta into soil at one time is that decomposition proceeds relatively slowly and the soil may be unable to accommodate frequent repeated applications. This condition apparently was reached at a loading equivalent to about 800 tons (wet weight) per acre after the third successive load at intervals of 2 months.

Waste applied at lower rates decompose more rapidly, thereby conserving the soils assimilative capacity, and the ability to accept repeated applications at more frequent intervals. More time must be spent, however, on the waste disposal aspect of the farming operation.

If an abundance of land were available, the highest loading rate consistant with the avoidance of nuisance conditions would be preferred. The extended time interval available between successive loads would insure the destruction of most of the organic matter, thus restoring the soils' assimilative capacity. If only a limited land area were available, however, lower loadings and more frequent successive loads would be indicated as a means of more fully utilizing the ability of the soil to serve as a disposal medium. These broad generalizations can serve as guidelines for establishing a loading regimen; the details must necessarily be worked out with field experience.

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POULTRY MANURE DISPOSAL IN SOIL: ITS EFFECT UPON THE SOIL WATER AND THE SOIL

Termination Report Of The
Field Experiment and Field Experiment Analytical Phase

prepared by Joseph E. Steckel

The incorporation of farm animal manures into soil has been practiced, in fact encouraged, for hundreds of years. The practice increases crop yield due to nitrogen fertilization. Present animal management procedures result in the accumulation of large amounts of animal manure on small areas of land. Disposal of this manure is a problem of major concern. The soil may be a natural disposal site for very large amounts of animal manures.

Trials in New Jersey by Professor Charles H. Reed Agricultural Engineering Department, have shown the practicality of the Plow-Furrow-Cover method (PFC) of poultry manure disposal. The liquid poultry manure is deposited in an opened furrow and then is covered immediately by plowing the next furrow, all in one operation. Soil with a moisture content appropriate for plowing will shear onto and cover the manure in the furrow. The soil will cover completely a manure layer 2 inches thick when the manure has a solid content of 20%. This PFC system is physically capable of the disposal of 400 metric tons of fresh poultry manure per hectare or 100 metric tons of water-free poultry manure per hectare (200 and 50 tons/ A. respectively).

The disposal of 400 metric tons of fresh poultry manure into a hectare of soil is 20 times greater than the conventional practice. The effect from such a disposal on the soil and on the quality of soil percolate water is not known. The limitations of disposal of manure in soil will be evaluated in this study.

EXPERIMENTAL CONSIDERATIONS AND PLAN

Disposal of poultry manure implies that large amounts of manure will be removed from the troublesome site. As a procedure, disposal of poultry manure in soil implies that the disposal amount will exceed by several times the presently recognized application amounts. The PFC disposal scheme will incorporate 20 times more poultry manure into soil than that conventionally practiced for fertilization.

Disposal of 100 metric tons of water-free poultry manure/ha (45 tons/A) results in the addition of large amounts of nutrient to the soil, e.g., table 3, 3300 and 8160 kg/ha of nitrogen and calcium, respectively (3000 and 7400 lbs/A). This application amounts to 80 metric tons of organic matter/ha (35 tons/A). Trials have indicated that this amount of manure disappears visually in 6 to 8 weeks. A manure loading of this magnitude will have a marked effect on the chemical reactions occurring in the soil.

The ability of soil to retain cations is well known. These cations include potassium, calcium, magnesium, sodium, and ammonium which are present in the manure. The clay minerals in the soil are responsible for retention of the cations. The ability of the soil to not retain anions is well known. These anions include nitrate, nitrite, chloride, bicarbonate, and sulfate. Phosphate is an exception. It combines with aluminum and iron (with calcium in some cases) to form very insoluble phosphate compounds -- fixation of phosphate.

The cation retained by the soil is called exchangeable cation. The amount of exchangeable cation is expressed commonly as concentration, milliequivalents/100 gram of soil (meq/100 g). The capacity of the soil to retain cations is called the cation exchange capacity (CEC). CEC represents the sum of all the exchangeable cations such as K, Ca, Mg, Na, NH_4, H, and Al. When large amounts of cations are added to the soil, such as by manure disposal, retention of cations will occur in that portion of the soil adjacent to the disposed material and at the same time the concentration of material dissolved in the soil water will increase.

The soil moisture content is changed by evaporation or by rainfall. The soil moisture content, with rainfall, may increase to a value in excess of field capacity. At this time percolation or downward movement of water will occur. The downward movement of soluble material in the percolating water is called leaching. When leaching occurs, the soil volume below the manure disposal position will be subjected to increased concentrations of cations and anions. Soluble cation will be attracted by the clay mineral of the soil and the downward movement of the cation will be slowed. Soluble anion will continue to move downward with the soil water. Ionic balance will be maintained in the soil water. Generally, the soil water will contain bicarbonate and nitrate as anions and calcium and hydrogen as the cations. The content of soluble material in the soil water will be influenced by the amount of manure added, the soil moisture content, the amount of rainfall, the amount of percolation and leaching, and the soil depth at which the soil water is sampled. Other factors also will influence the content of soluble material.

The general plan of the experiment was to take soil samples periodically after the poultry manure disposal. These samples were analyzed for: the exchangeable cations K, Ca, Mg, Na, and NH_4; the cation exchange capacity; the water extractable anions, NO_3+NO_2, Cl and SO_4; and the weak acid fluoride extractable PO_4. In addition, soil water samples were collected with suction lysimeters for chemical analysis of the elements named above.

The exchangeable cation and cation exchange capacity values obtained at various depths from the soil sites with manure disposal would serve as the measure of cation mobility and retention thru the soil profile. The water extractable anions and extractable phosphate values from soil samples collected at different depths would serve as a measure of the mobility and retention of anions thru the soil profile. The change in element concentration in the soil water samples would serve as a measure of the movement of both cations and anions in soil water.

The chemically determined amounts of cation and anion in both the soil and soil water samples obtained at the various soil depths would be summed or integrated for the soil profile sampled. Thus a single value would represent the total amount of element recovered from the manure treated soil. Untreated sites were sampled on the same dates and at the same depths for comparison purposes.

The concentrations of cations and anions determined at the various soil depths would serve to locate the depth at which retention occurred. The data from the sequence of the sampling dates would indicate the rate with which these elements moved thru the soil profile.

A major concern in the plan was to accumulate data which would provide conclusions relative to: the movement of cations and anions thru the soil profile; the accumulation or retention of cations and anions; and the recovery or balance of cations and anions.

EXPERIMENTAL PROCEDURES

Treatments and Experimental Design. This experiment was conducted at the Soils and Crops Research Center at Adelphia, New Jersey. The soil is Freehold loamy sand. The amounts of poultry manure applied into the soil by Plow-Furrow-Cover (PFC) were: none, 34, 67, and 101 metric tons of water-free poultry manure per hectare (15, 30, and 45 tons/A, table 1 for metric conversion). The Plow-Furrow-Cover depth was 17 cm (7 inches). The PFC applications were made on June 6, August 2, and October 15, 1968. The experiment was factorial in design: 4 amounts of poultry manure, 3 times of application, and 3 replicates. In addition a split application treatment was included, i.e., half applications of poultry manure on each of the dates May 5 and August 2, 1968 to make 34, 67, and 101 t/ha. The schedule of applications is shown in table 2.

There were a total of 48 plots each of which were 2.4 meters wide and 4.2 meters long (8 by 14 feet). The plots were not cropped during 1968 and 1969. The experiment extended over an area 25.5 meters wide and 94.2 meters long (85 by 314 feet).

Poultry Manure Sampling. The poultry manure slurry was agitated in the 2835 liter trailer tank (750 gallons) for 30 minutes prior to sampling. Two separate liter samples were taken for chemical analysis. Subsamples were taken for moisture determination. The volume of poultry manure slurry required for the particular application amount was calculated from the moisture content of the subsamples. The amounts of chemical element added to the soil via the poultry manure are shown in table 3.

Soil Water Sampling By Suction Lysimeter. Soil water samples were collected on the dates shown in table 2. The soil water samples were taken with suction lysimeters positioned at soil depths of 30, 45, 60, 90 and 120 cm (12, 18, 24, 36, and 48 inches, table 1). A 10 to 20 ml sample of soil water was obtained in one to two hours with a tension of 0.8 to 0.6 bar. No sample could be collected when the soil moisture was lower than 18%, volume basis. The suction lysimeters were positioned on the plots about 4 weeks after PFC. An 8 cm circle of 5 mil polyethylene was positioned just below the plow depth. This polyethylene circle was fitted tightly to the pipe body of the suction lysimeter to prevent downward channeling of water.

The porous ceramic cups of each lysimeter were cleaned with

Table 1. Standard Conversions of Metric System to English System

Weight/Area	Length
1 kg/ha = 0.9 lb/A	15 cm = 6 inches
2 = 1.8	22.5 = 9
3 = 2.7	30 = 12
4 = 3.6	37.5 = 15
5 = 4.5	45 = 18
6 = 5.4	60 = 24
7 = 6.3	75 = 30
8 = 7.2	90 = 36
9 = 8.1	105 = 42
10 = 9.0	120 = 48
1000 kg/ha = 1 metric ton (t)/ha	
34 t/ha = 15 tons/A.	
67 = 30	
101 = 45	

Table 2. Schedule of PFC Application, Soil Sampling, and Suction Lysimeter Sampling Dates.

PFC Date	Soil Sample Date	Rainfall, inches	Suction Lysimeter Sample Date	Rainfall, inches
1st PFC on:				
June 6, 1968	July 2, 1968	7.21		
	July 29,	1.47	Aug. 1, 1968	8.68
	Aug. 26,	6.84	Aug. 27,	6.84
	Oct. 2,	1.60	Oct. 14,	3.35
	June 11, 1969	22.19	July 1, 1969	29.59
	Aug. 12,	18.23	Aug. 7,	10.83
	Nov. 25,	11.37		
	Total Rainfall	68.91		59.29
2nd PFC on:				
Aug. 2, 1968	Aug. 26, 1968	6.44		
	Oct. 2,	1.60	Oct. 14, 1968	11.09
	June 11, 1969	22.19	July 2, 1969	29.59
	Aug. 12,	18.23	Aug. 7, 1969	10.83
	Nov. 25,	11.37		
	Total Rainfall	59.83		51.51
3rd PFC on:				
Oct. 15, 1968	June 11, 1969			
	Aug. 12,	18.23		
	Nov. 25,	11.37		
	Total Rainfall	51.79		
Split Application PFC:				
One half May 5, 1968	Aug. 12, 1969	64.78		
One half Aug. 2, 1968	Nov. 25, 1969	11.37		
	Total Rainfall	76.15		

Table 3. Amounts of Chemical Element in the Poultry Manure Disposed By PFC on Three Dates.

kg chemical element/ha

Chemical Element	Poultry Manure, Date Applied and Amount, t/ha								
	June 6, 1968			Aug. 2, 1968			Oct. 15, 1968		
	34	67	101	34	67	101	34	67	101
N	1100	2200	3300	900	1800	2700	930	1860	2790
P	830	1660	2490	830	1660	2490	870	1740	2610
K	930	1860	2790	990	1980	2970	810	1620	2430
Ca	2720	5440	8160	2850	5700	8550	2760	5520	8380
Mg	275	550	825	300	600	900	275	550	825
Na	220	440	660	250	500	750	150	300	450
SO_4	450	900	1350	450	900	1350	300	600	900
Cl	450	900	1350	330	660	990	390	780	1170

5% hydrochloric acid after the suction lysimeters were constructed. Passage of the hydrochloric acid was continued until the calcium content in the solution was lowered to 5 or fewer ppm.

Soil water content, volume basis, was determined on individual plots with a Nuclear-Chicago neutron probe on each date that suction lysimeter water samples were taken. The neutron probe measurements were taken at 15 cm intervals (6 inches) from 30 to 150 cm soil depth (1 to 5 feet).

Soil sampling. Soil cores of 4 cm diameter (1½ inches) were taken to a depth of 120 cm (4 feet) from the experimental plots. These soil cores were segmented as follows: 0 to 15 cm for the first segment (0 to 6 inches) and each subsequent segment was 7.5 cm (3 inches) for a total of 15 core segments. Duplicate cores from each experimental plot were taken on all of the soil sampling dates shown in table 2 except for November 25, 1969 when one soil core was taken. The core segments were air dried, pulverized, and passed thru a 2 mm sieve for subsequent analysis.

Nutrient Extraction From The Soil Samples. Potassium, calcium, magnesium, and sodium were extracted from 10 gram soil samples with pH 7.0 ammonium acetate (1N) by using an equilibrium-leaching technique. The cation exchange capacity was determined by exchanging the ammonium ion with 10% potassium chloride solution (pH 2.5). Exchangeable ammonium was determined on a second soil sample using a solution of 10% sodium chloride and 0.5% hydrochloric acid and overnight equilibrium.

Nitrate, chloride, and sulfate were extracted from the air dry soil samples with water. Phosphate was extracted from the soil with a dilute acid-fluoride solution (Bray #1).

Chemical Analysis. Chemical analysis was performed with a Technicon AutoAnalyzer arranged to determine as many as 5 elements simultaneously and 40 samples each hour. Potassium and sodium were determined by flame photometer with lithium as the internal standard. Calcium and magnesium were determined colorimetrically with murexide and magnesium blue respectively. Ammonium-nitrogen (NH_4-N) was determined with the indolphenol method. Nitrate and nitrite-nitrogen (NO_3+NO_2-N) was determined using the naphthyl ethylenediamine dihydrochloride method of Kamphake. Chloride was determined using the mercury thiocianate and ferric ammonium sulfate method of O'Brian. Sulfate was determined using barium chloride and a sodium EDTA washout. Phosphate was determined with ammonium molybdate and chlorostannous acid as the reductant.

Many different manifolds and combinations of aliquot aspirating tubes were developed to provide for analysis of the widely differing concentrations of elements as found in the soil water samples, the ammonium acetate extracts, the cation exchange capacity solutions, the exchangeable ammonium solutions, the water extract solutions from soil, and the Bray #1 solutions.

Data Management. The management of the great volume of data has been accomplished using the facilities of the Rutgers Center for Computation and Information Service. The facilities of the center in the last 3 years have evolved from IBM 1620 to IBM 7040 to IBM 360 model 67.

The statistical analysis of the data has been accomplished by use of the Biomedical programs from the University of California. One major program was written to provide for the transition of chemical analysis instrument readings to element concentration and to maintain a complete identification of the sample. The identification number involved 17 digits. The major task of translating numbers to punch cards was accomplished by using the IBM 1230 optical mark score reader. A second major program was written to provide for the integration of the element in the soil profile sampled. The procedure used was a modification of Simpson's rule. A third program was written to manage the neutron probe data and to convert element concentration in the soil water to the weight of the element dissolved in the soil water.

NUTRIENT CONTENT IN SOIL WATER FROM SUCTION LYSIMETERS

A change in the concentration of element in the soil water is an indication of the movement of nutrient in the soil profile. The data in table 4 show the increased concentration of nitrate plus nitrite nitrogen in the soil water collected from the same depth but from sites with an increasing amount of poultry manure PFC. A concentration of 700 ppm of nitrogen was found 391 days after PFC at a depth of 90 cm (3 ft) when 101 t of poultry manure/ha (45 tons/A) had been applied. At the same depth where no poultry manure had been applied the concentration was 1 ppm. Similar increases in concentration were found for other elements when the amount of poultry manure PFC was increased.

The water content of soil changes with time and with depth in the soil. Consequently the concentration of nutrient in the soil water was expected to vary with the changing water content. Moreover, the concentration of the element as a single measurement does not indicate the amount of the element in the soil horizon. To quantitize the element contained in the soil horizon from which the soil water was collected by suction lysimeter, the soil water content, volume basis, was measured on the same day and at the same collection depth. The mathematical product of the element concentration in ppm times the percent volume water content times 1.1 equals the kilogram weight of the element dissolved in the soil water in a soil volume of one hectare by 11 cm thick. These weight values of dissolved element are suitable for reporting the weight of soluble element in the soil horizon. Furthermore, the weights for the soil horizon may be integrated for the soil profile. Concentration values as ppm in the soil water may be estimated from the values in appendix tables 1 thru 9 as follows: the weight of element dissolved times 90 divided by the soil moisture content, volume basis. The soil moisture content ranged from 20 to 33%, however, 25% is appropriate for estimation of the concentration.

The amounts of water soluble cations integrated over the 22 to 120 cm soil profile (9 to 48 inches) are shown in table 5. In all cases the amount of cation increased as the amount of poultry manure PFC was increased. The maximum amount of potassium, 481 kg/ha, was found in the soil profile receiving 101 t of poultry manure (45 tons PM/A). In the case of ammonium - N, the amount was found to decrease at each sampling date. Only 2 kg of NH_4-N were found in the 22 to 120 cm soil profile on August 7, 1969 or 428 days after PFC.

Table 4. Concentration of NO_3+NO_2-N in the Soil Water Sampled by Suction Lysimeter

(ppm N, averages of 2 or 3 replicates)

Soil Depth Sampled, cm	Poultry Manure Applied, t/ha. 1/							
	0	34	67	101	0	34	67	101
	Sampled October 14, 1968				Sampled July 1, 1969			
30	5	135	120	280	35	125	120	200
45	5	100	125	70	12	40	120	400
60	4	100	25	36	6	30	220	500
90	2	10	12	13	1	90	290	700
120	2	2	7	2	10	250	590	450

1/ Poultry manure applied PFC on June 6, 1968.

Table 5. Amounts of Cation Dissolved in the Soil Water Occurring in the 22 to 120 cm Depth at Five Sampling Dates After Disposal of Poultry Manure on June 6, 1968.

(averages of 2 or 3 replicates)

Element	Poultry Manure Treatment, t/ha 1/	Sampling Date and Days From PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		kg/22 to 120 cm soil depth for ha				
Potassium	None	25	57	4	10	8
	34	71	229	170	52	33
	67	86	142	163	107	74
	101	130	481	88	229	132
Calcium	None	118	110	94	65	65
	34	303	431	554	179	134
	67	356	625	613	437	256
	101	345	761	784	897	665
Magnesium	None	36	29	22	13	21
	34	84	175	264	59	34
	67	108	149	261	165	74
	101	131	242	277	267	157
Sodium	None	10	61	35	10	9
	34	78	121	110	41	26
	67	78	220	130	165	65
	101	162	664	135	167	142
Ammonium-Nitrogen	None	4	3	-	1	-
	34	34	11	9	-	-
	67	95	3	41	-	-
	101	228	161	50	11	2

1/ Water-free poultry manure.

The integrated amounts of water soluble anions are shown in table 6. In all cases the amount of anion increased as the amount of poultry manure increased. The amount of NO_3+NO_2-N in the soil profile was maximum, 1129 kg/ha, on July 1, 1969 or 391 days after PFC. In contrast, the amount of chloride decreased steadily from 790 to 147 kg/ha on the sampling dates 83 and 428 days after PFC. The decrease in Cl is the result of downward movement of soil water (59.29 inches of rain) to remove Cl from the soil profile. The slower movement of NO_3+NO_2-N is normal because of: 1.) a natural delay in mineralization and nitrification, 2.) immobilization of NO_3 by soil microorganisms and subsequent release.

The maximum amount of phosphate, 7.7 kg/ha (table 6), was found 428 days after PFC in the soil profile treated with 101 t poultry manure (45 tons). The data of phosphate soluble in the soil water show a trend of a slow increase over the 428 day period. This trend is not surprizing since the amount of phosphorus added was 2490 kg of P/ha (table 3).

The amounts of cation and anion in the soil profile from the second PFC, August 2, 1969 (table 2) are presented in tables 7 and 8. The maximum amount of NH_4-N on October 15 was 556 kg N dissolved in the soil water to a depth of 120 cm (4 ft). This soil profile had received 11.09 inches of natural rainfall in the 73 days between PFC and soil water sampling. By the next sampling date of July 2, 1969 (334 days and 35.33 inches of rainfall), the amount of NH_4-N had decreased to 50 kg N. This NH_4-N decrease was probably due to nitrification. Table 8 presents the data for NO_3+NO_2-N after the second PFC. The maximum amount of NO_3+NO_2-N on October 14 was 517 kg and on July 2, 1969 the maximum amount was 964 kg of N dissolved in the soil water to a depth of 120 cm (4 ft). On this same date, July 2, 1969, the soil profile receiving no poultry manure contained soil water with 9 kg of N dissolved in the 120 cm profile depth (4 ft).

The weights of cation and anion dissolved in the soil water as sampled at depths of 30, 45, 60, 90 and 120 cm are presented in appendix tables 1 thru 9.

Data have been presented showing the weight of dissolved nutrient in the soil on successive sampling dates after disposal of poultry manure into soil at a depth of 17 cm. The amount of NH_4-N decreased with time. The amount of NO_3+NO_2-N increased to large amounts in 391 and 334 days after the disposals had been made. The large amounts, 1146 and 964 kg N/ha,

Table 6. Amounts of Anion Dissolved in the Soil Water Occurring in the 22 to 120 cm Depth at Five Sampling Dates After Disposal of Poultry Manure on June 6, 1968.

(averages of 2 or 3 replicates)

Element	Poultry Manure Treatment, t/ha 1/	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		kg/22 to 120 cm soil depth for ha				
NO_3+NO_2-N	None	33	55	36	22	21
	34	191	387	619	205	155
	67	136	185	466	579	221
	101	124	719	650	1129	640
Chloride	None	76	14	8	48	10
	34	402	297	210	39	20
	67	307	371	310	154	57
	101	460	790	583	364	147
Sulfate	None	78	202	145	100	105
	34	99	325	176	67	101
	67	108	392	194	98	134
	101	319	816	205	133	160
Phosphate	None	1.2	-	2.4	0.6	0.2
	34	-	8.7	6.2	1.5	4.2
	67	-	-	3.6	1.3	3.3
	101	-	10.5	3.7	4.0	7.7

1/ Water-free poultry manure.

Table 7. Amounts of Cation Dissolved in the Soil Water Occurring in the 22 to 120 cm Depth at Three Sampling Dates After Disposal of Poultry Manure on August 2, 1968.

(averages of 2 or 3 replicates)

Element	Poultry Manure Treatment, t/ha 1/	Sampling Date and Days from PFC on Aug. 2, 1969		
		Oct. 14, 1968 73 days	July 2, 1969 334 days	Aug. 7, 1969 370 days
		kg/22 to 120 cm soil depth for ha		
Potassium	None	84	68	10
	34	149	68	47
	67	157	233	129
	101	409	454	272
Calcium	None	73	164	75
	34	375	128	145
	67	359	585	370
	101	320	679	570
Magnesium	None	29	8	19
	34	149	55	39
	67	173	186	102
	101	177	229	187
Sodium	None	29	61	14
	34	95	35	37
	67	160	250	127
	101	338	244	223
Ammonium-Nitrogen	None	6	-	2
	34	66	1	-
	67	370	51	-
	101	556	11	1

1/ Water-free poultry manure.

Table 8. Amounts of Anion Dissolved in the Soil Water Occurring in the 22 to 120 cm Depth at Three Sampling Dates After Disposal of Poultry Manure on August 2, 1968.

(averages of 2 or 3 replicates)

Element	Poultry Manure Treatment, t/ha 1/	Sampling Date and Days from PFC on Aug. 2, 1969 Oct. 14, 1968 73 days	 July 2, 1969 334 days	 Aug. 7, 1969 370 days
		kg/22 to 120 cm soil depth for ha		
NO_3+NO_2-Nitrogen	None	22	9	22
	34	517	122	130
	67	405	802	328
	101	194	964	795
Chloride	None	-	110	11
	34	309	23	17
	67	1168	317	74
	101	1071	220	106
Sulfate	None	-	130	120
	34	-	92	111
	67	-	229	213
	101	-	118	164
Phosphate	None	4	-	2
	34	7	2	2
	67	2	3	2
	101	7	2	2

1/ Water-free poultry manure.

should not be expected to be retained by the soil proper or by the soil microorganisms. In fact, with additional rainfall this NO_3+NO_2-N will be carried downward by the soil water to the ground water table. The magnitude of 1000 kg of N/ha may be best appreciated by recognizing that very few farming enterprizes add as much as 250 kg of N/ha in a crop year.

The amounts of K, Mg, NH_4, Cl, and SO_4 dissolved in the soil water had peaked and had decreased considerably on August 7, 1969 or 428 days after PFC. In general the peak amounts were observed in the sampling of August 27, 1968 or 83 days after PFC. The Ca soluble in the soil water had not peaked at 428 days after PFC which indicates that Ca was being leached thru the soil profile. NO_3+NO_2-N amounts in the soil water on August 7, 1969 were lower than on July 1, 37 days earlier. PO_4 soluble in the soil water increased over the 428 day period.

CATION RETENTION IN THE SOIL

When large amounts of cations are added to a soil, the retention of the cations may well be identified as accumulation although the retention of a particular cation may be less than the amount of that cation which had been added.

Samples of soil, collected to a depth of 120 cm and over a 537 day period, were analyzed chemically for exchangeable K, Ca, Mg, Na, and NH_4-N. The concentrations, milliequivalents (me) of cation/100 grams of soil, were studied as follows: 1) for downward movement, 2) for accumulation at specific depths in the soil, and 3) for mobility and accumulation relative to the number of days after the manure application.

Exchangeable Potassium: Distribution in the Soil Profile

The distribution of exchangeable K in the soil profile with time is presented in Figure 1. At 26 days after 1PFC on June 6, 1968 (7.21 inches of rainfall), the highest accumulation of exchangeable K occurred at the 30 cm depth. At 81 days after the PFC (August 28 and 15.82 inches of rain), exchangeable K supplied by the 34, 67, and 101 t/ha manure application had leached to a depth of 45 cm in the soil. Soil samples collected at 537 days after application showed that exchangeable K had leached to the 90 cm depth in the soil.

Although accumulation at depths below 60 cm was observed, the greatest accumulation of exchangeable K occurred between the 30 and 60 cm soil depths. Accumulation below the 90 cm depth was not observed. In general as the amount of poultry manure applied was increased and as the time between application and sampling increased, the concentration of exchangeable K increased throughout the 120 cm depth of soil.

The distributions of exchangeable K in the soil for the August 2 manure applications (2PFC) and the October 15 manure applications (3PFC) were similar to the 1PFC distribution (Figure 2). The concentration of exchangeable K below the 60 cm depth was less for 1PFC than for 2PFC or 3PFC. This is believed to be the result from the different amounts of rainfall (68.91, 59.83, and 51.79 inches, respectively, Table 2).

These results from three different times of application and from three different sites in the experimental field indicate that exchangeable K moved downward in the soil. However,

Figure 1. EXCHANGEABLE POTASSIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC ON JUNE 6, 1968 .

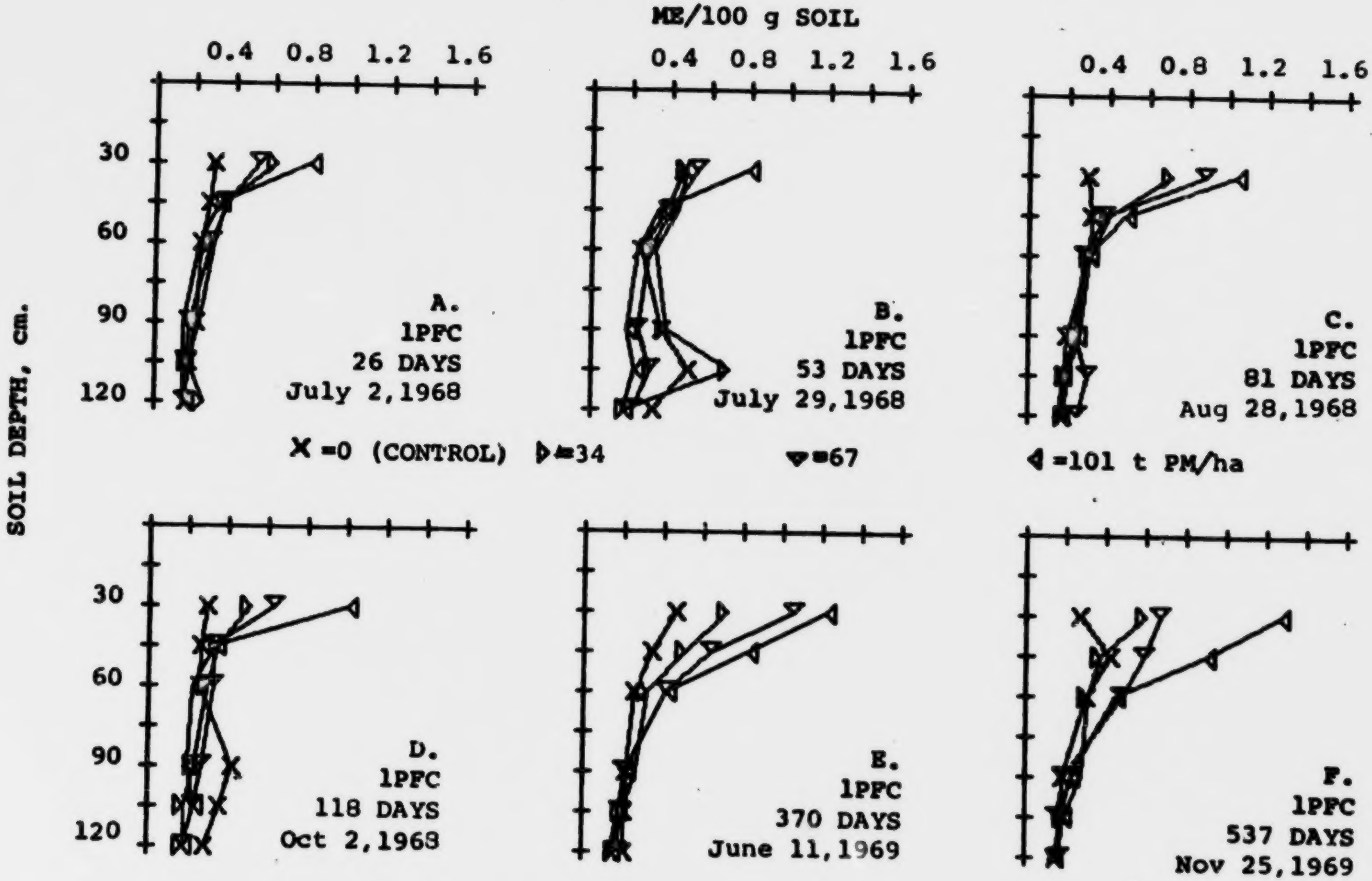
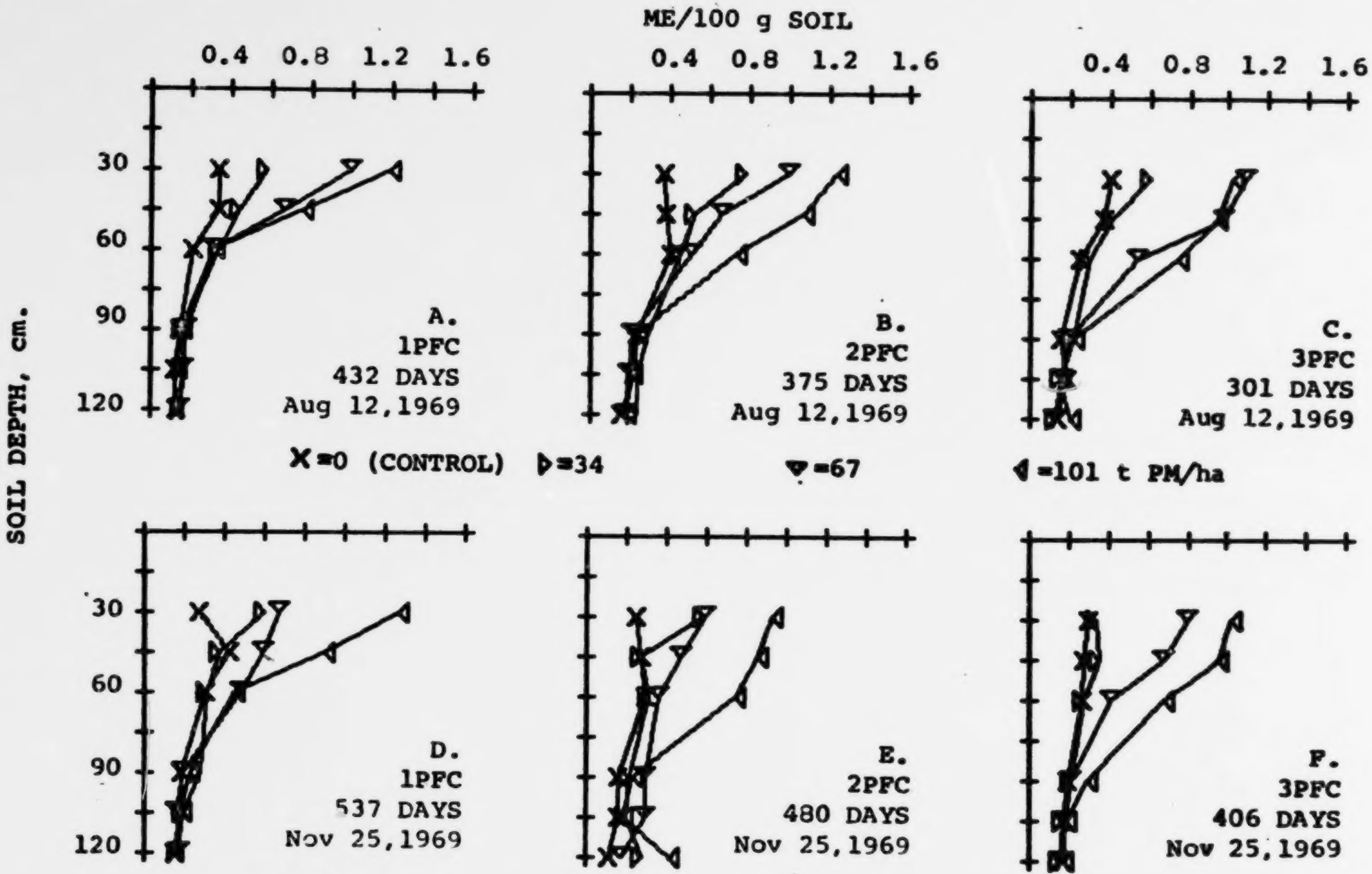


Figure 2. EXCHANGEABLE POTASSIUM: DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC, AND 3PFC.



for all poultry manure applications, the exchangeable K occurred predominantly in the 30 to 60 cm depth of soil.

Exchangeable Potassium: Summed for the Soil Profile Studied.

The summed exchangeable K in the 22.5 to 120 cm soil profile depth increased with increased amounts of poultry manure and with an increase in the number of days from application to soil sampling (Figure 3). The summed exchangeable K weights were not significantly different for the first four sampling dates (118 days after application). On June 11, 1969 (370 days after application) the summed exchangeable K weights were 389, 652, and 900 kg/ha greater for the 34, 67, and 101 t/ha manure treatments, respectively, than the control plot. On November 25, 1969 (537 days after application) the summed K weights were 273, 511, and 1164 kg/ha greater than the control.

Summed exchangeable K weights for the 2PFC and the 3PFC applications are shown in Figure 4. In general, a pattern similar to the 1PFC application was observed. The increase in weight of exchangeable K with increased loading of manure is well demonstrated for all of the sampling dates for 2PFC and 3PFC.

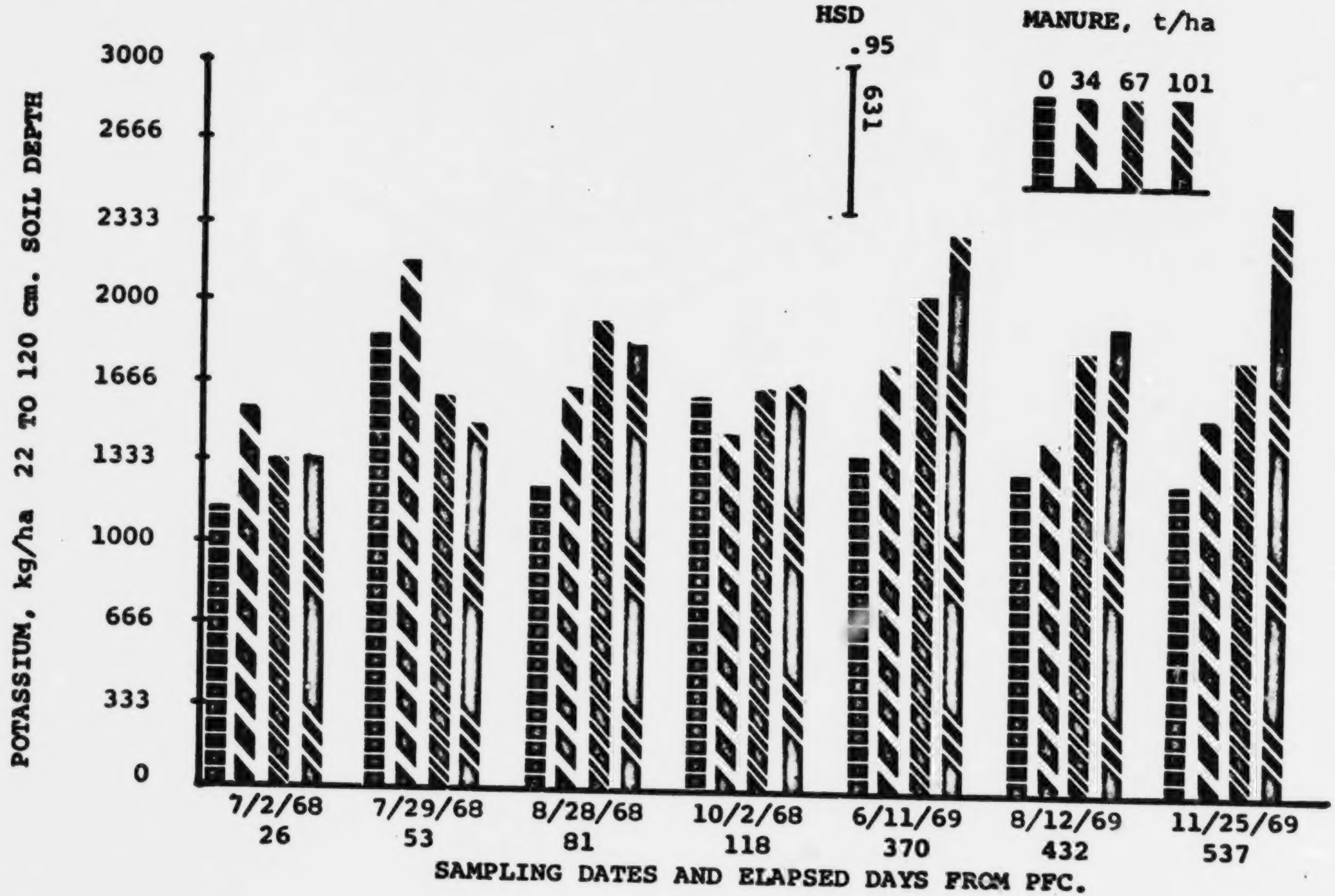
In general, the control and the 34 t/ha manure plots were not statistically different. The summed exchangeable K in the 101 t/ha plots was always greater than the 67 t/ha plots. The exchangeable K in the 67 and 101 t/ha plots was significantly larger than the 34 t/ha and the control plots. These results also indicate that the summed exchangeable K differences between amounts of poultry manure were accentuated with increasing number of days after the manure application.

Exchangeable Calcium: Distribution in the Soil Profile.

The maximum exchangeable Ca of 4.0 me/100 g was found at the 30 and 45 cm soil depths when sampled at 26 and 53 days after 1PFC on the 101 t/ha manure plots. The amount of exchangeable Ca then decreased progressively with depth in the soil and with increased number of days to levels which were lower than those in the control plots (Figure 5). At 118 days after 1PFC the 34 and 67 t/ha manure plots had less exchangeable Ca than the control (Figure 5, graph D).

Samples collected 315 days after 2PFC show the amounts of Ca found in the first 60 cm soil depth for the 34 and 101 t/ha

Figure 3. EXCHANGEABLE POTASSIUM : SUMMED FOR THE 22 TO 120 cm. SOIL DEPTH (1PFC ON JUNE 6, 1968).



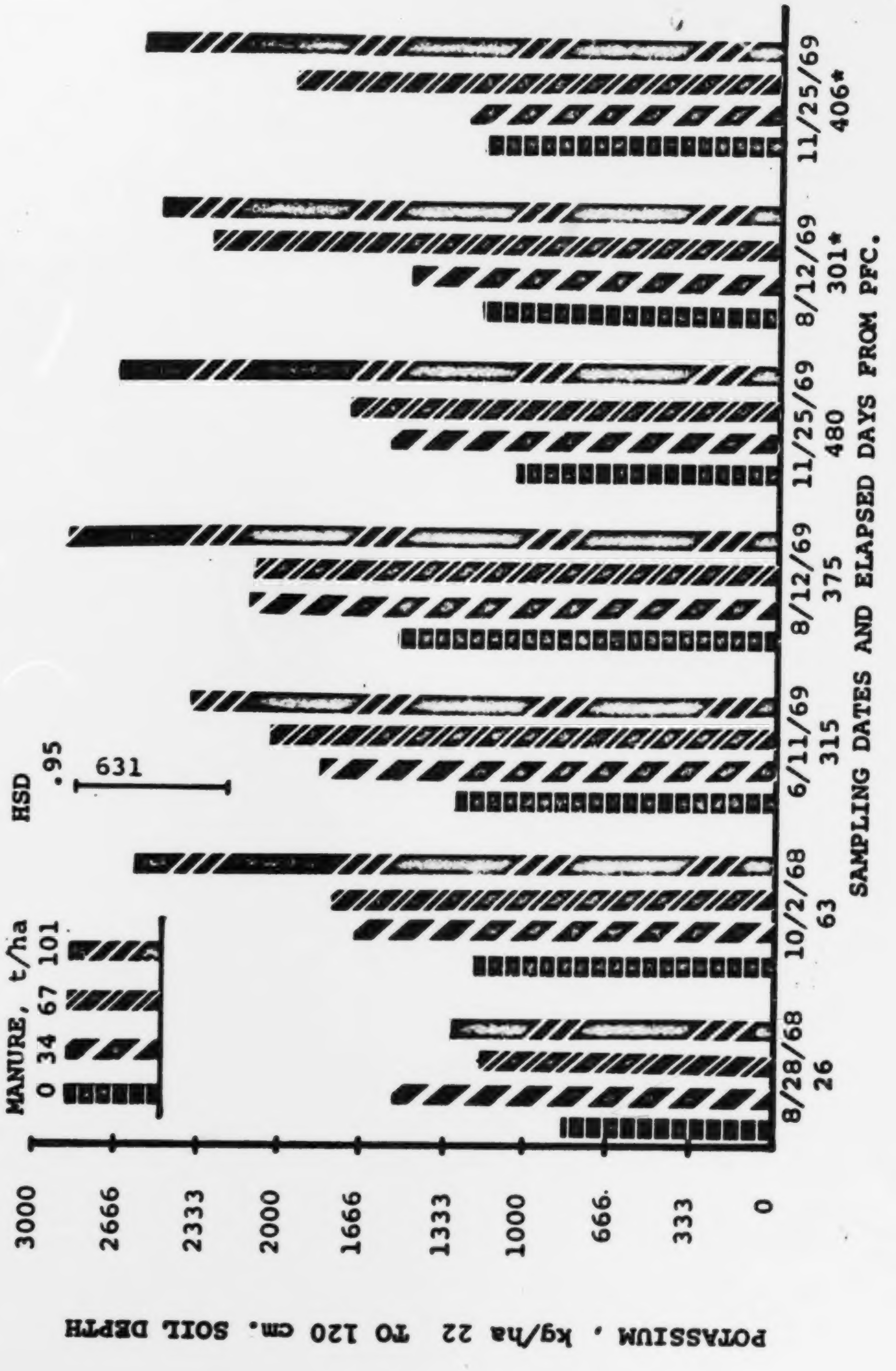
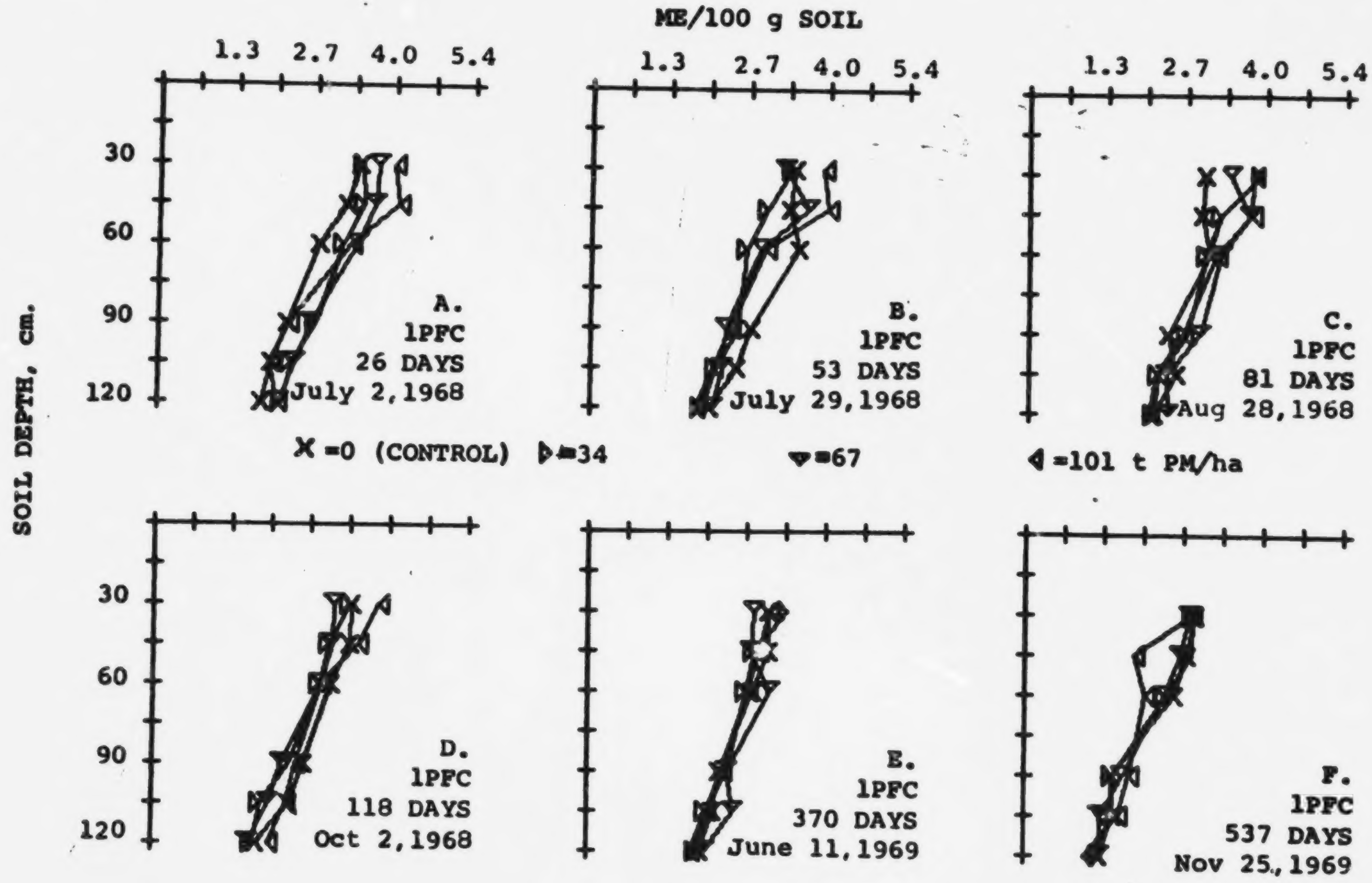


Figure 4. EXCHANGEABLE POTASSIUM : SUMMED FOR THE 22 TO 120 cm. SOIL DEPTH (2PFC ON AUGUST 12, 1968 AND 3PFC* ON OCTOBER 15, 1968).

Figure 5. EXCHANGEABLE CALCIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC ON JUNE 6, 1968 .



manure applications were less than in the control plots. This trend is striking on samples taken 480 days after 2PFC (Figure 6, graph E) where the exchangeable Ca was less in the treated plots than in the control.

In general the soil samples taken on August 12 and November 25, 1969 (Figure 6) show a decrease in exchangeable Ca from the depth of 45 to 90 cm depth. This decrease is greater on 1PFC and 2PFC manure application plots than on the 3PFC.

Exchangeable Calcium: Summed for the Soil Profile Studied.

The summed exchangeable Ca values for the-22.5 to 120 cm soil profile depth studied were not significantly influenced by the amounts of poultry manure which had been applied on June 6, 1968 (Figure 7) although the amounts of Ca added in the manure were 2760, 5520, and 8380 kg/ha. This soil depth, 22.5 to 120 cm, did not include the soil into which the manure had been applied (15 to 22.5 cm depth).

Although exchangeable Ca in the soil was not influenced by the manure applications, the amount of Ca dissolved in the soil water obtained by suction lysimeter was markedly increased by amounts of manure added. Figure 8 shows the summed amounts of Ca dissolved in the soil water present in the 22 to 120 cm soil depth. Increased amounts of poultry manure increased the amounts of dissolved Ca for any particular suction lysimeter water sampling date. Dissolved Ca increased to a maximum of 897 kg/ha at 391 days after manure application and then decreased. These values demonstrate that Ca was mobile although retention of Ca by the soil as measured by exchangeable Ca had not been found.

The soil pH values were determined on the soil samples collected on August 12, 1969 (Table 9). The soil pH was increased at the 15 cm depth where the manure had been applied, however at depths of 30, 45, 60, 90 and 120 cm the soil pH values had been lowered. At a depth of 90 cm the soil pH was lowered by approximately 0.4 pH unit on the plots where 101 t/ha of manure had been applied.

One hundred forty four of the soil samples collected on November 25, 1969 were selected for a "total calcium" determination (one hour boiling in perchloric acid). The analysis of variance showed a highly significant interaction between amount of manure applied and soil depth. The interaction data (Table 10) show that "total calcium" at three soil depths was nearly constant where no manure had been applied. However where 101

Figure 6. EXCHANGEABLE CALCIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC, AND 3PFC.

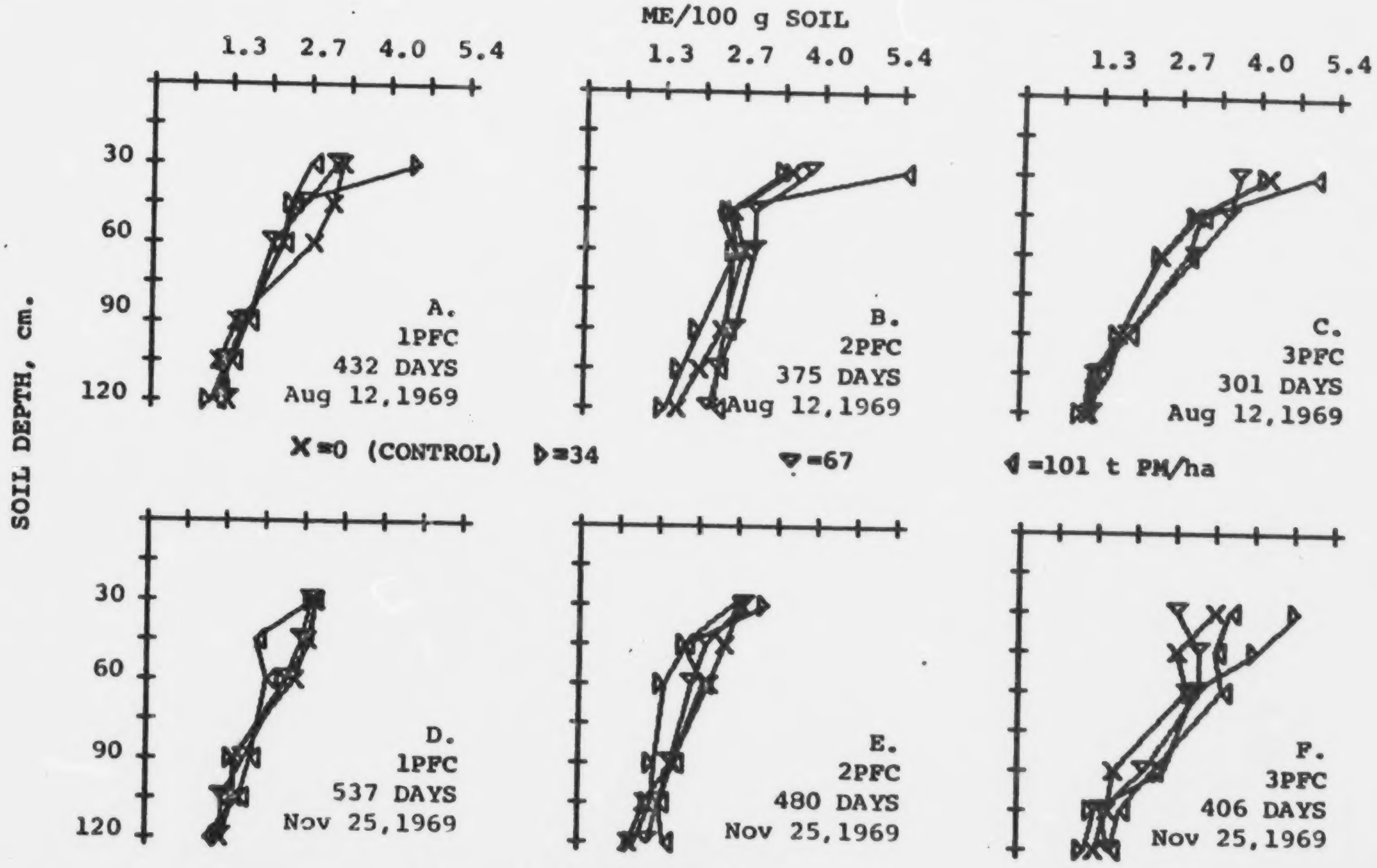


Figure 7. EXCHANGEABLE CALCIUM SUMMED FOR THE 22 TO 120 cm. SOIL DEPTH (1PFC ON JUNE 6, 1968).

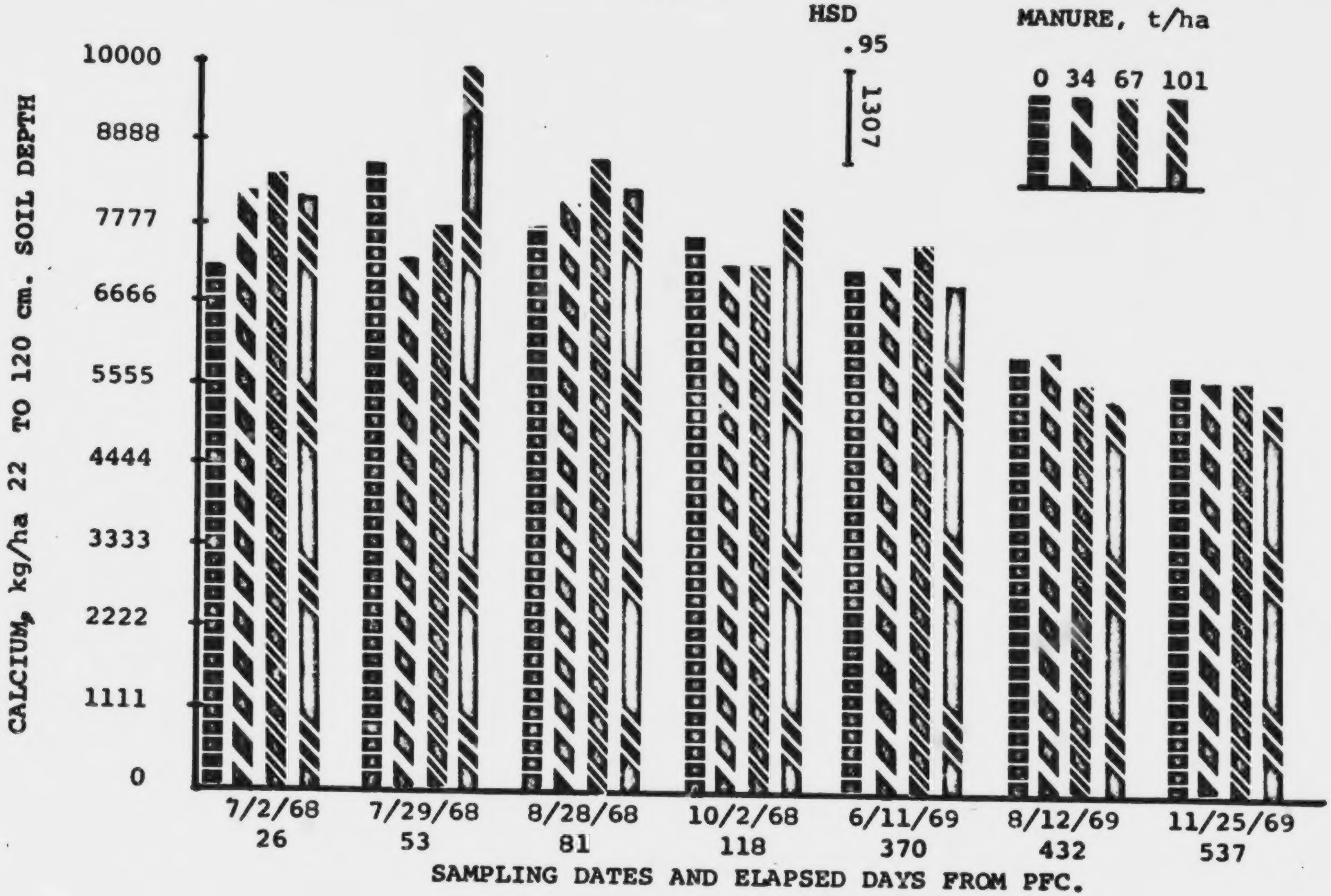


Figure 8. CALCIUM DISSOLVED IN THE SOIL WATER OCCURRING IN THE 22 TO 120 cm. SOIL DEPTH (1PFC ON JUNE 6, 1968 AND 2PFC* ON AUGUST 2, 1968).

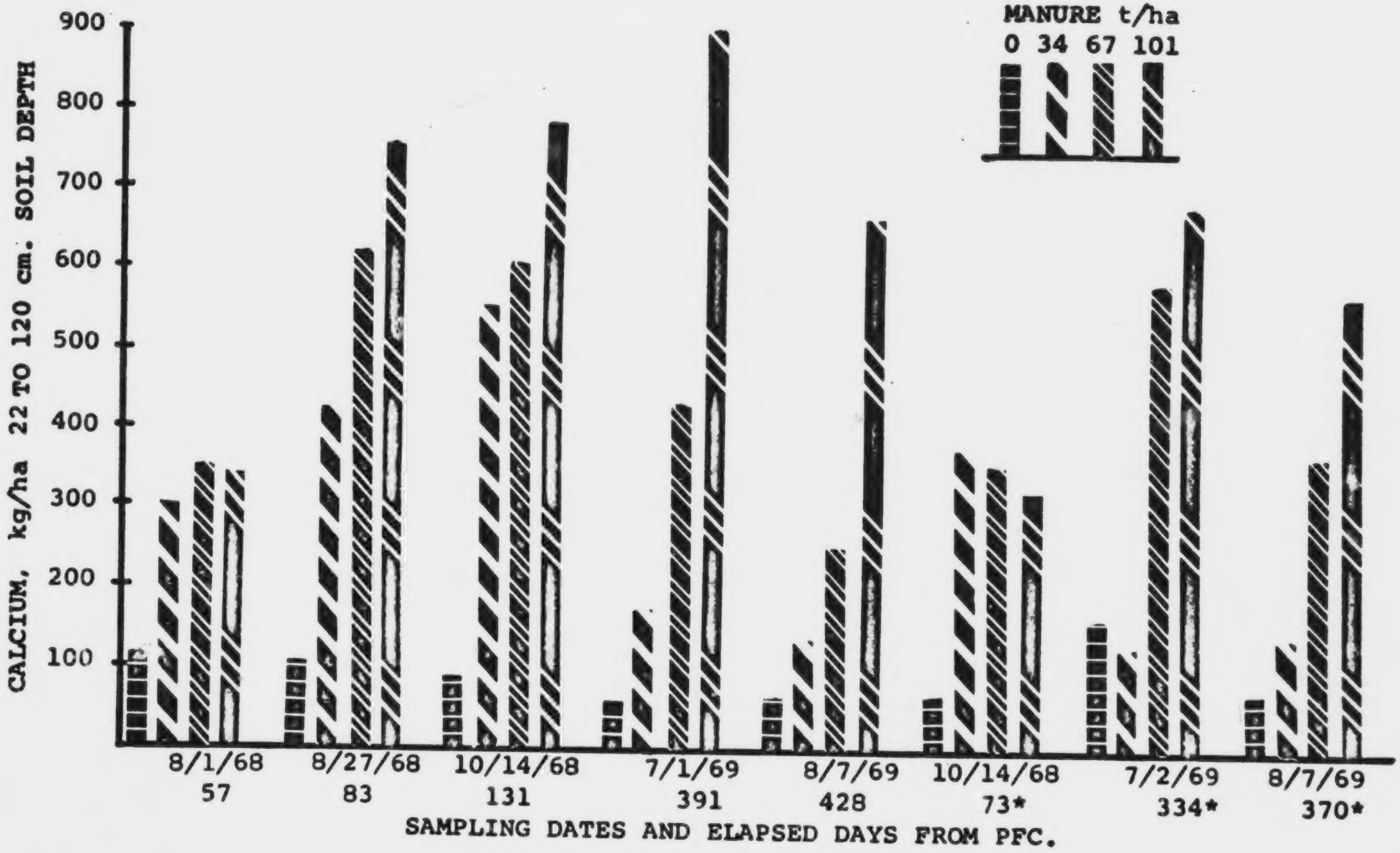


Table 9. Soil pH Values at Various Depths After Poultry Manure Application (average of three replicates)

Soil 1/ Depth, cm	Poultry Manure Applied, t/ha							
	0	34	67	101	0	34	67	101
	on June 6, 1968				on August 2, 1968			
15	6.12	6.38	6.22	6.17	5.61	5.93	6.01	6.04
30	6.05	5.73	5.71	6.07	5.73	5.89	5.80	6.21
45	5.18	5.38	5.15	4.78	4.88	5.16	4.80	4.80
60	4.85	5.19	4.72	4.56	4.75	4.69	4.61	4.44
90	4.77	4.80	4.69	4.43	4.73	4.72	4.58	4.47
120	4.77	4.66	4.78	4.40	4.70	4.65	4.64	4.51
	on October 16, 1968				on May 5 and August 2, 1968 2/			
15	6.18	6.18	5.90	6.53	6.47	6.09	6.29	6.18
30	6.16	5.27	5.09	5.41	6.10	5.30	5.57	5.31
45	5.14	4.89	4.62	4.77	5.03	5.04	4.98	4.83
60	4.71	4.50	4.39	4.29	4.67	4.66	4.61	4.69
90	4.56	4.43	4.23	4.18	4.69	4.61	4.62	4.54
120	4.54	4.49	4.24	4.36	4.71	4.59	4.56	4.49

1/ Soil Sampled on August 12, 1969.

2/ Equal P.M. applications on each date for total of 34, 67, and 101 t/ha, respectively.

t/ha of manure had been applied, the "total calcium" was a maximum of 29.9 me/100g in the 15 to 22.5 cm soil depth where the manure had been applied. Moreover considerable Ca had moved down into the 22.5 to 30 cm soil depth of the 101 t/ha of manure plot. These data demonstrate that a large amount of Ca had been retained in the 15 to 22.5 cm soil depth - the zone of the soil into which the manure had been applied.

The "total calcium" data were summed for the 0 to 30 cm soil depth using an assumed soil bulk density of 1.5 (Table 11). Summed "total calcium" increased significantly with increased amounts of manure, however the differences between manure application dates (1PFC, 2PFC, etc) were not significantly different. These summed "total calcium" data represent Ca recoveries as follows: 53, 101, and 119% of the Ca added in the manure in the 34, 67, and 101 t/ha amounts, respectively.

The exchangeable Ca summed, the water soluble Ca summed, the soil pH values, and the "total calcium" data make a rather complete picture. Ca is retained in the manure application zone of the soil as insoluble chemical salts of phosphate and perhaps sulfate and carbonate. The large amount of insoluble Ca salt will increase the Ca concentration in the soil water for a period of time after the manure application. With greater passage of time the water soluble Ca concentration would be expected to decrease. The natural enzymatic oxidation to form nitrate ion is accompanied by the formation of 2 hydrogen ions from each ammonium ion. This hydrogen ion supply will maintain Ca mobility thru the soil with a subsequent decrease in soil pH and a decrease in exchangeable Ca in the soil.

Exchangeable Magnesium: Distribution in the Soil Profile.

The distribution of exchangeable Mg in the soil showed an increase with increasing amounts of manure applied (Figure 9). The exchangeable Mg decreased with increasing depth, however downward movement did take place. Figure 10 (graph E) shows considerable accumulation of Mg at the 45 to 105 cm soil depth when 101 t/ha of poultry manure had been applied 480 days prior to soil sampling.

Exchangeable Magnesium: Summed for the Soil Profile.

The summed exchangeable Mg in the 22.5 to 120 cm soil profile depth increased with increased manure applied and showed a tendency to increase with an increased number of days after

Table 10. "Total Calcium" at Different Soil Depths After Different Loads of Poultry Manure (Soil Sampled November 25, 1969).

HSD Between 4 Treatment Means: 0.95 = 3.354 : 0.99 = 4.179
Averaged Over Three Replicates

	me/100 g of Soil			
Soil Depths	Poultry Manure t/ha			
(cm)	0	34	67	101
0 - 15	9.373	10.187	15.628	19.568
15 - 22.5	9.145	13.067	22.155	29.938
22.5 - 30	8.030	9.213	9.257	14.053

Table 11. Summed "Total Calcium" in the 0 to 30 cm Soil Depth (Soil Sampled November 25, 1969).

HSD Between 4 Treatment Means: 0.95 = 7029.9 : 0.99 = 8943.0
Averaged Over Three Replicates

PM: t/ha					kg/ha 0 - 30 cm
	Manure Applications				
PM	1PFC	2PFC	3PFC	SPFC	Ave. of All PFC's
0	6750	5300	9010	8800	7465
34	9600	7830	9650	8660	8935
67	11520	11190	14180	15610	13125
101	22060	19450	13620	14600	17430

Figure 9. EXCHANGEABLE MAGNESIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC ON JUNE 6, 1968 .

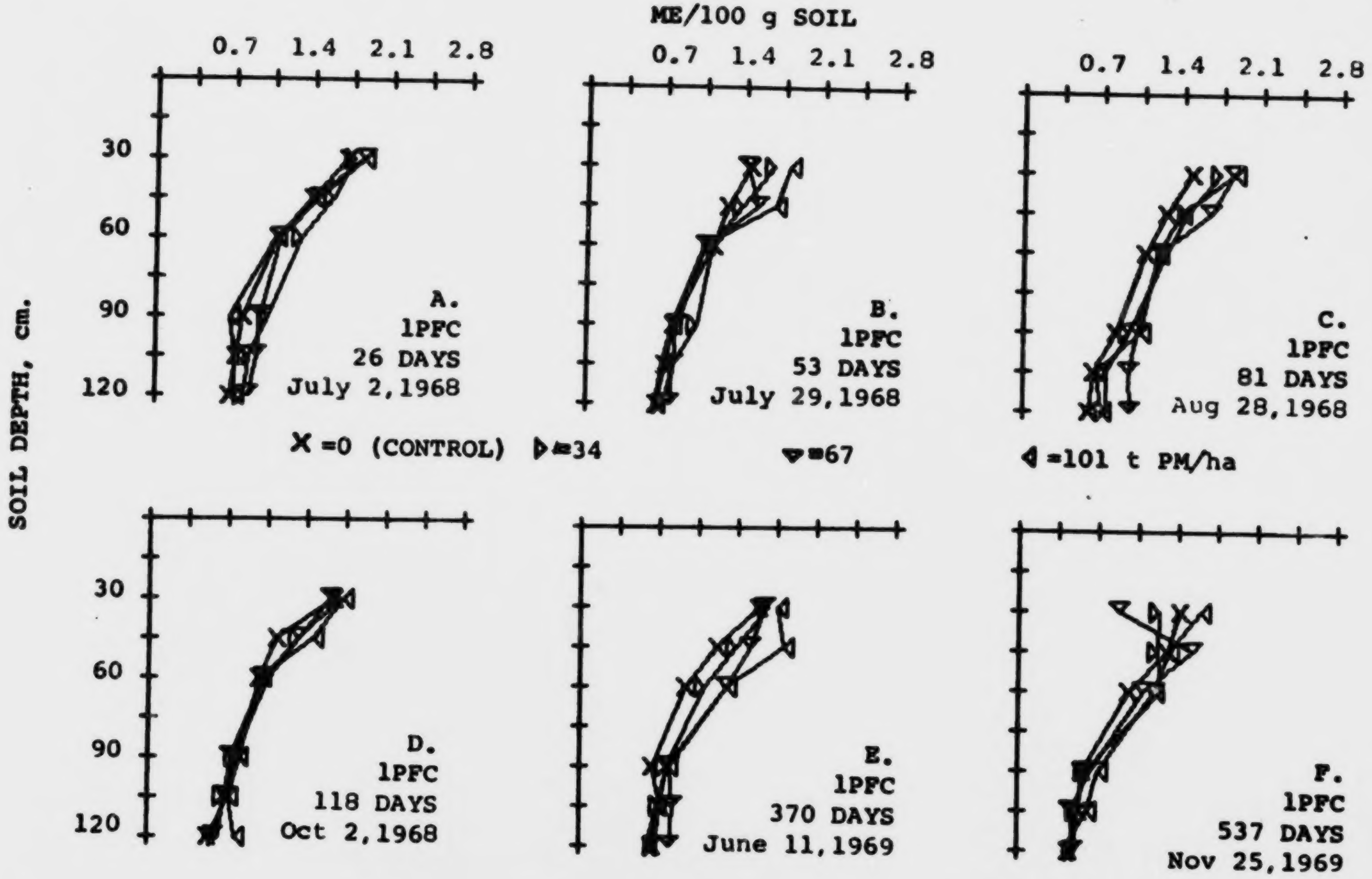


Figure 10. EXCHANGEABLE MAGNESIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC, AND 3PFC.

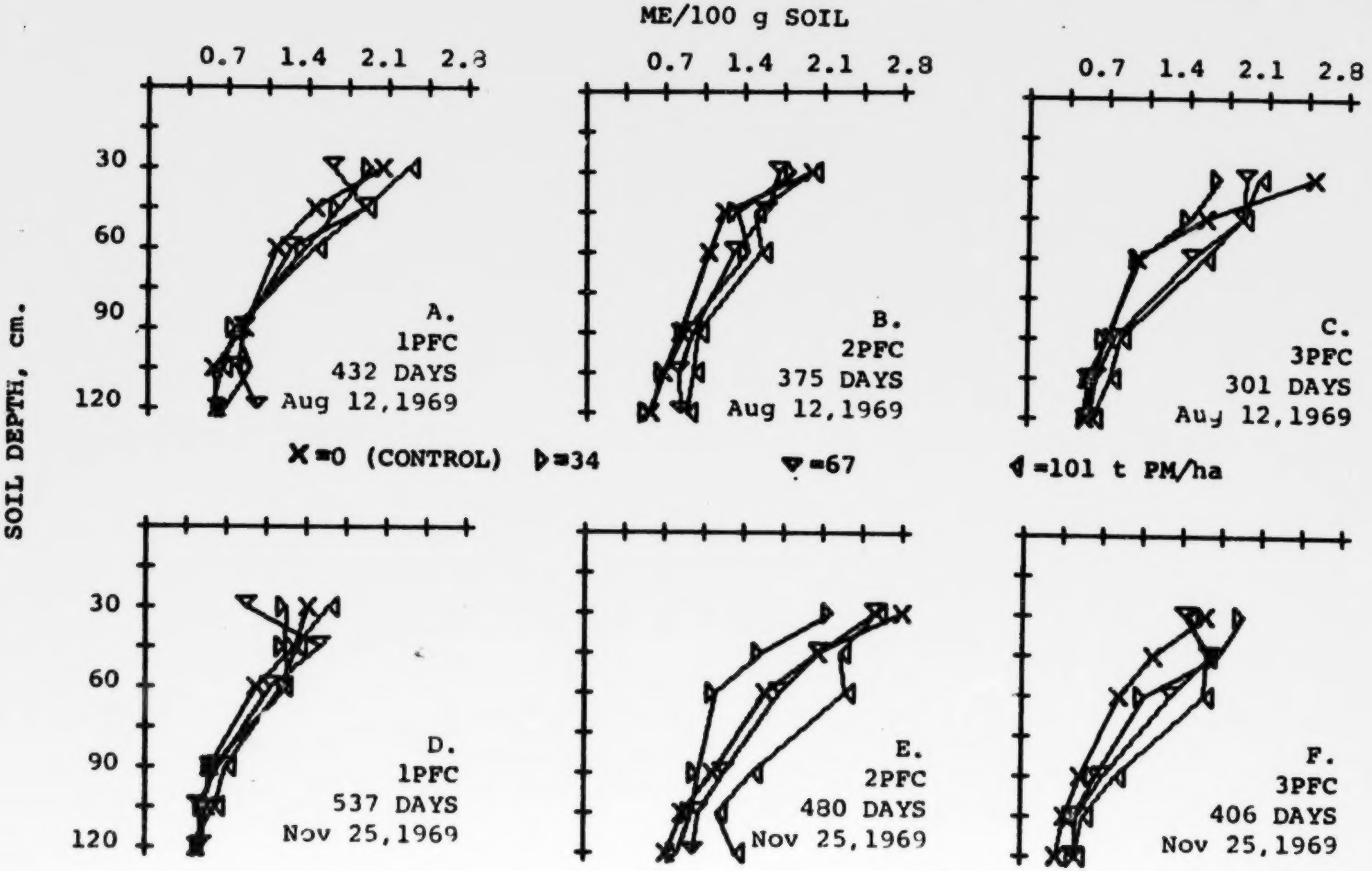
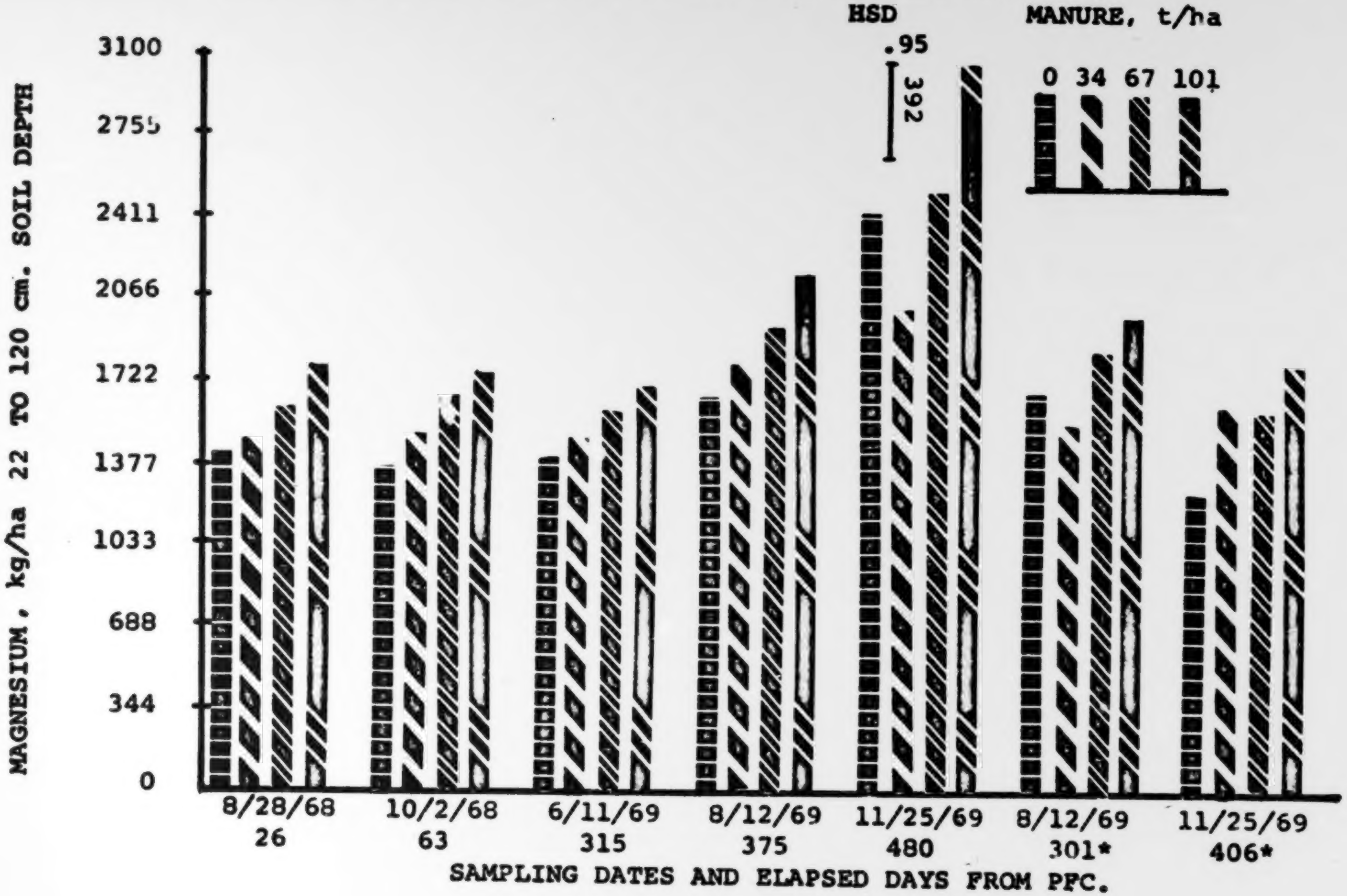


Figure 11. EXCHANGEABLE MAGNESIUM : SUMMED FOR THE 22 TO 120 cm. SOIL DEPTH (2PFC ON AUGUST 12, 1968 AND 3PFC* ON OCTOBER 15, 1968).



manure application (Figure 11).

Exchangeable Sodium: Distribution in the Soil Profile.

The distribution of exchangeable Na in the 22.5 to 120 cm soil profile was not markedly influenced by manure when the soil was sampled 26 days after the manure applications (Figure 12, graph A), however the distribution at 81 days after application was strongly influenced by the amount of manure applied. Soil samples collected 480 days after 2PFC (Figure 13, graph E) showed the largest accumulation of exchangeable Na occurring at the 60 to 120 cm depths where 101 t/ha of manure had been applied.

These results demonstrate sodium leaching from shallow to deeper soil depths as the number of days increased from application of manure to soil sampling date.

Exchangeable Sodium: Summed for the Soil Profile.

The summed exchangeable Na for the 22.5 to 120 cm soil profile depth was not influenced by increasing amounts of manure 26 days after 1PFC. Amount of manure did increase summed exchangeable Na in the profile when sampled 81 days after manure application. At 537 days after 1PFC of 101 t/ha manure the summed exchangeable Na was 454 kg/ha for the 22.5 to 120 cm depth. The control plot was 255 kg/ha. This shows a remarkable persistence of exchangeable Na in the profile even after 68.9 inches of rainfall.

Exchangeable Ammonium-N: Distribution in the Soil Profile.

Exchangeable NH_4-N in the 0 to 120 cm soil profile depth increased with increasing amounts of poultry manure and decreased with increasing time after the manure applications. Exchangeable NH_4-N was distributed through the entire soil profile that was sampled.

Figure 14 shows the distribution of exchangeable NH4-N in the soil profile at six different soil sampling dates after the manure application made on June 6, 1968 (1PFC). The exchangeable NH_4-N at the 30 cm depth decreased from 2.19 me/100g at 26 days to 1.64 me/100g at 81 days after 1PFC for the 101 t/ha manure treatment. The control plot at the same depth on the same sampling dates had exchangeable NH_4-N values of 0.22 and

Figure 12. EXCHANGEABLE SODIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC ON JUNE 6, 1968 .

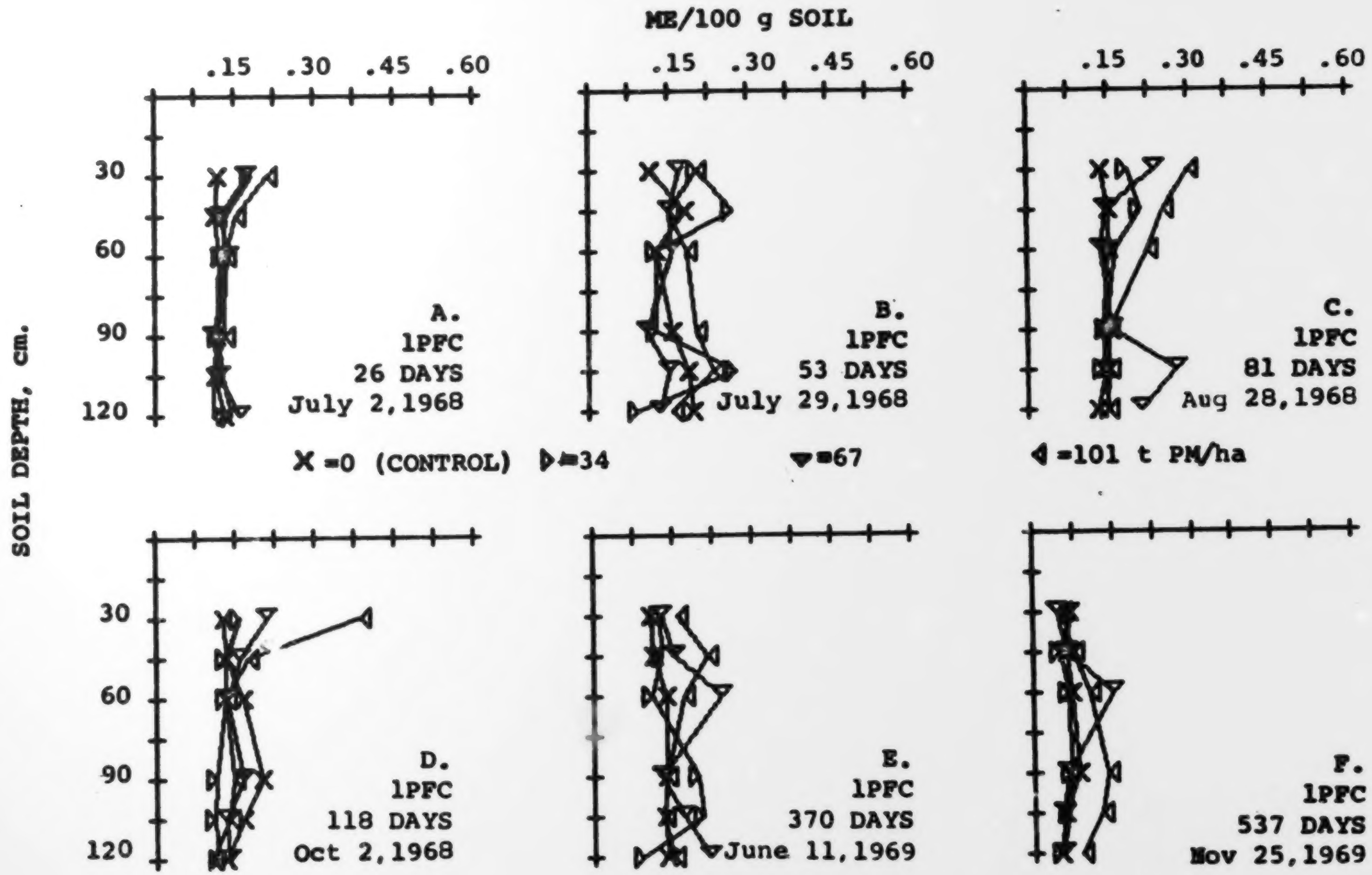


Figure 13. EXCHANGEABLE SODIUM : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC, AND 3PFC.

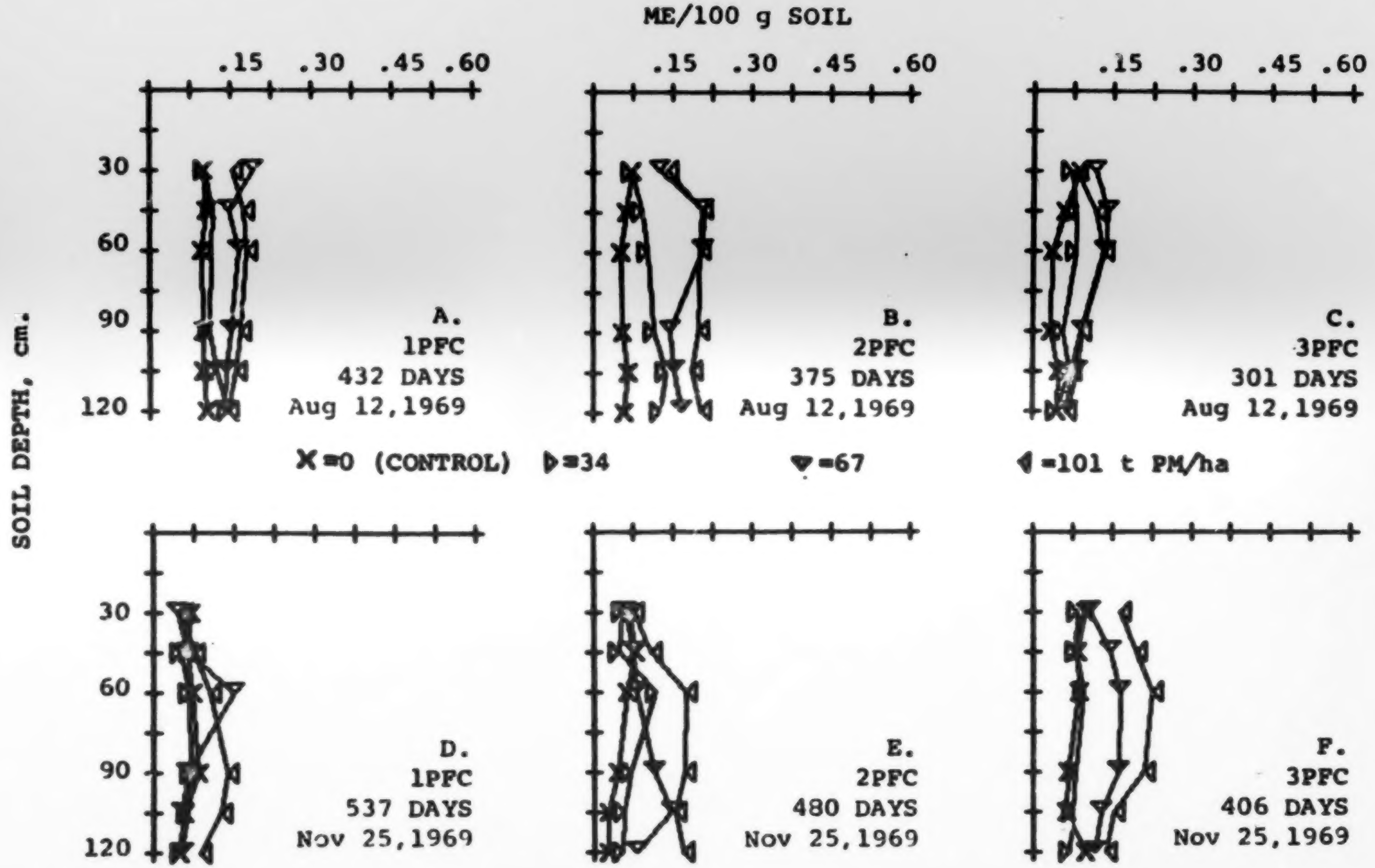
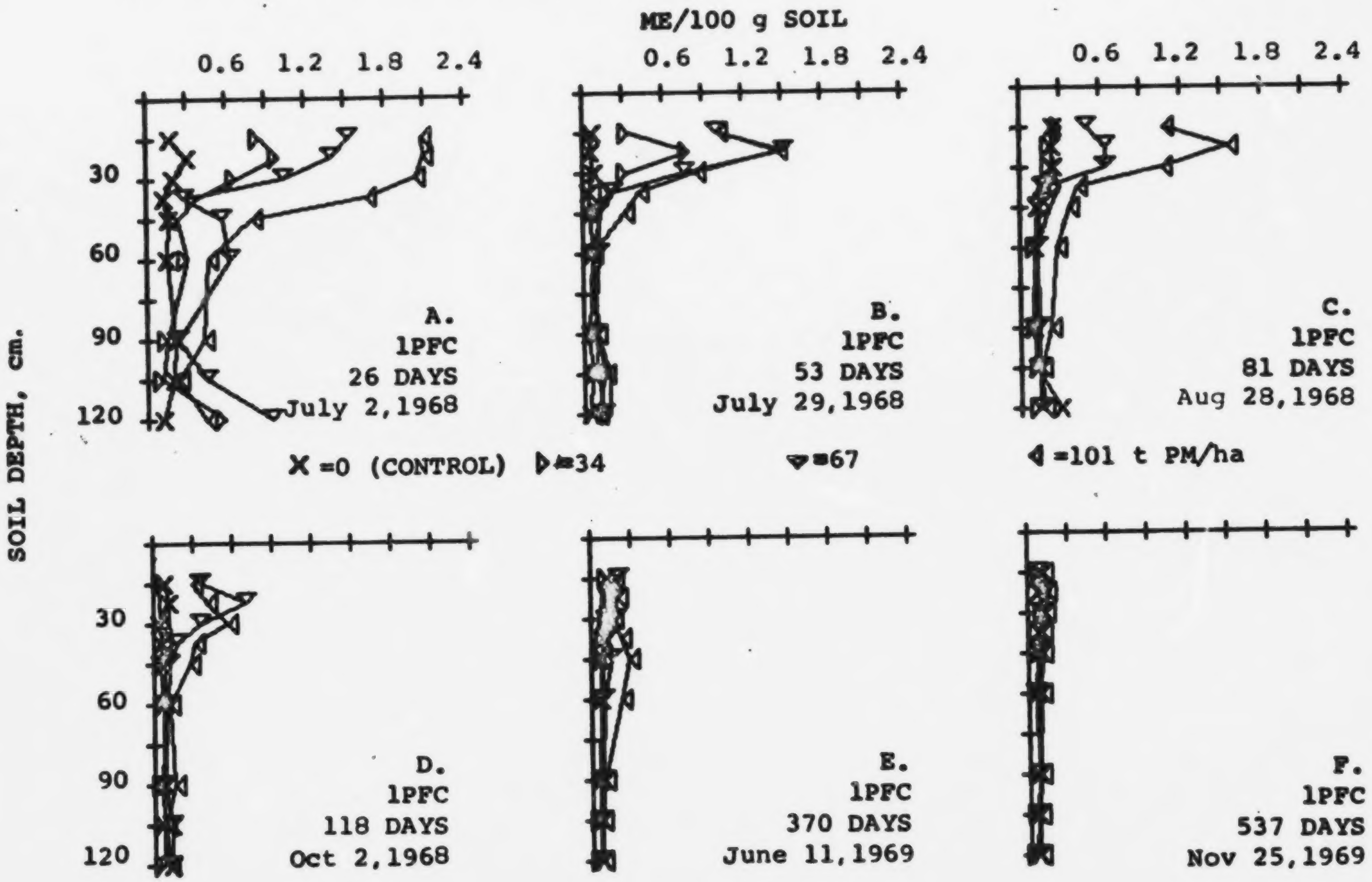


Figure 14. EXCHANGEABLE AMMONIUM-N : DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC ON JUNE 6, 1968 .



0.26 me/100g, respectively. At 81 days after the manure application, NH_4-N was found at a soil depth of 90 cm. At 118 days after manure application the exchangeable NH_4-N concentrations on the 67 and 101 t/ha manure treatments were greater than the control at soil depths from 15 to 45 cm, however NH_4-N in the 34 t/ha treatment was negligible. At 370 days after manure application a small increase of exchangeable NH_4-N for only the 101 t/ha treatment was observed over the control at the 45 and 60 cm depths (Figure 14, graph E). At 537 days none of the three manure plots had exchangeable NH_4-N concentrations greater than the control at any of the sampled soil depths.

The exchangeable NH_4-N concentrations in plots treated with poultry manure on August 2, 1968 followed the same distribution pattern as found in the June 6 application. The highest concentration of NH_4-N was 2.46 me/100g soil at a depth of 22.5 to 30 cm and 26 days after the 101 t/ha manure application. On October 2 (63 days after application) the exchangeable NH_4-N was found to be 1.19 me/100g, a 50% reduction in 37 days in which rainfall was 1.60 inches (Table 2).

The different dates of application of poultry manure into the soil, - June 6, August 2, and October 15, 1968 - markedly influenced the amounts of exchangeable NH_4-N on the soil sampling dates of August 12 and November 25, 1969 (Figure 15). The exchangeable NH_4-N decreased as the number of days after application increased. Downward movement of NH_4-N to deeper layers in the soil profile was observed. In fact, 0.98 me NH_4-N/100g was found at the 60 cm depth 406 days after application of 101 t/ha of manure while the control plot was 0.10 me/100g (Figure 15, graph F).

The distributions of exchangeable NH_4-N in the soil profile at nearly equal number of days after application of manure are shown in Figure 16, graphs A, B, and C. Graph A shows that nearly all of the NH_4-N had disappeared in 370 days (39.31 inches rainfall) after the June 6 application. Graph B shows that nearly all of the NH_4-N had disappeared in 375 days (48.46 inches rainfall) after the August 2 application. However, graph C shows significant exchangeable NH_4-N concentrations at the 60 cm depth where 101 and 67 t/ha of manure had been applied 406 days prior to the sampling of the soil (51.79 inches rainfall).

Water percolation through the soil profile and soil temperature are the most likely causes for these differences of exchangeable NH_4-N concentration in the soil. Increased rainfall should increase the volume of water percolating through the soil, however the manure plots receiving the largest rainfall (51.79

Figure 15. EXCHANGEABLE AMMONIUM-N: DISTRIBUTION IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC, AND 3PFC.

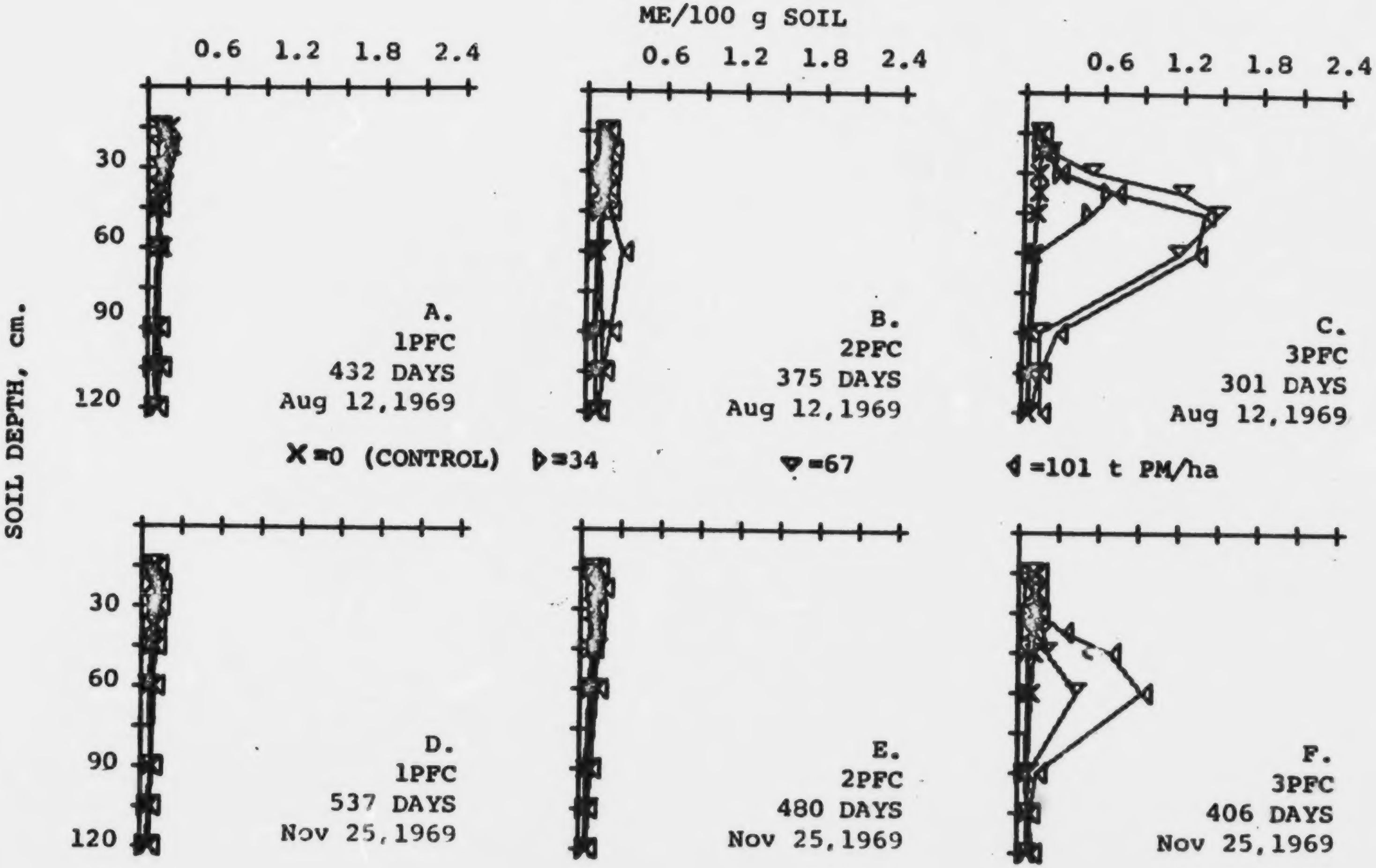
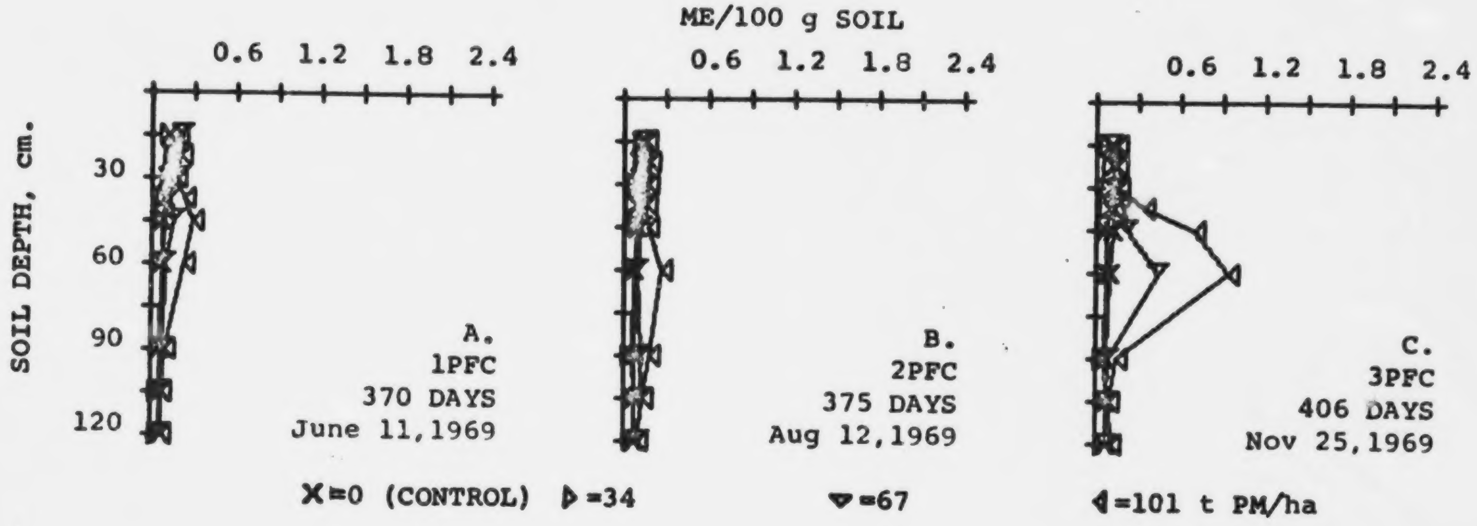


Figure 16. EXCHANGEABLE AMMONIUM-N: DISTRIBUTION IN THE SOIL PROFILE AT 370, 375, AND 406 DAYS AFTER 1PFC, 2PFC, AND 3PFC, RESPECTIVELY.



inches), were found to have the largest amounts of exchangeable NH_4-N. A natural increase in soil temperature after manure application (as in the case of the June 6 PFC) or a continuing high soil temperature after manure application (as in the case of the August 2 PFC) would result in considerable nitrification - oxidation of NH_4-N to NO_3-N. However, a natural and rapid decrease in soil temperature after manure application (as in the case of the October 15 PFC) would greatly decrease nitrification. Ammonium ion concentration will persist through the winter months, and downward mobility would be moderate due to the attraction of the positively charged ammonium ion and the negatively charged clay or colloidal particles in the soil. With greater clay content in the soil, the electrostatic charge effect on reduced mobility of ammonium ion will become more important and at the same time the percolation of water through the soil profile will be reduced. The interaction of these factors account for the longer persistance of ammonium-ion at greater depth in the soil when poultry manure application was made in late autumn or early winter.

Exchangeable Ammonium-N: Summed for the Soil Profile.

The summed exchangeable NH_4-N data for the 0 to 120 cm soil profile depth are shown in Figure 17. In soil samples taken 26 days after manure application the amounts of NH_4-N were 656, 1508, and 1947 kg/ha greater, respectively, in the 34, 67, and 101 t/ha manure plots than in the control plot. On October 2 (118 days after the manure application), the manure plots were found to have 16, 316, and 320 kg NH_4-N/ha more, respectively, than the control plot. These results indicate a great decrease in exchangeable NH_4-N in this 92 day period. The exchangeable NH_4-N contributed by manure application had almost disappeared from soil samples collected on November 11, 1969 (537 days after application of the manure).

Soil samples collected from the 2PFC application (August 2) showed the same distribution trends as the 1PFC manure application (Figure 18). However, the samples from the October 15 manure applications (3PFC) showed large amounts of exchangeable NH_4-N. These amounts of NH_4-N were found after a winter and a summer - a total of 406 days from the manure application time. These data show that application of large amounts of poultry manure in late autumn or early winter will lead to the persistance of large concentrations of exchangeable NH_4-N at a depth of 60 cm.

Figure 17. EXCHANGEABLE AMMONIUM-N : SUMMED FOR THE 0 TO 120 cm. SOIL DEPTH (1PFC ON JUNE 6, 1968).

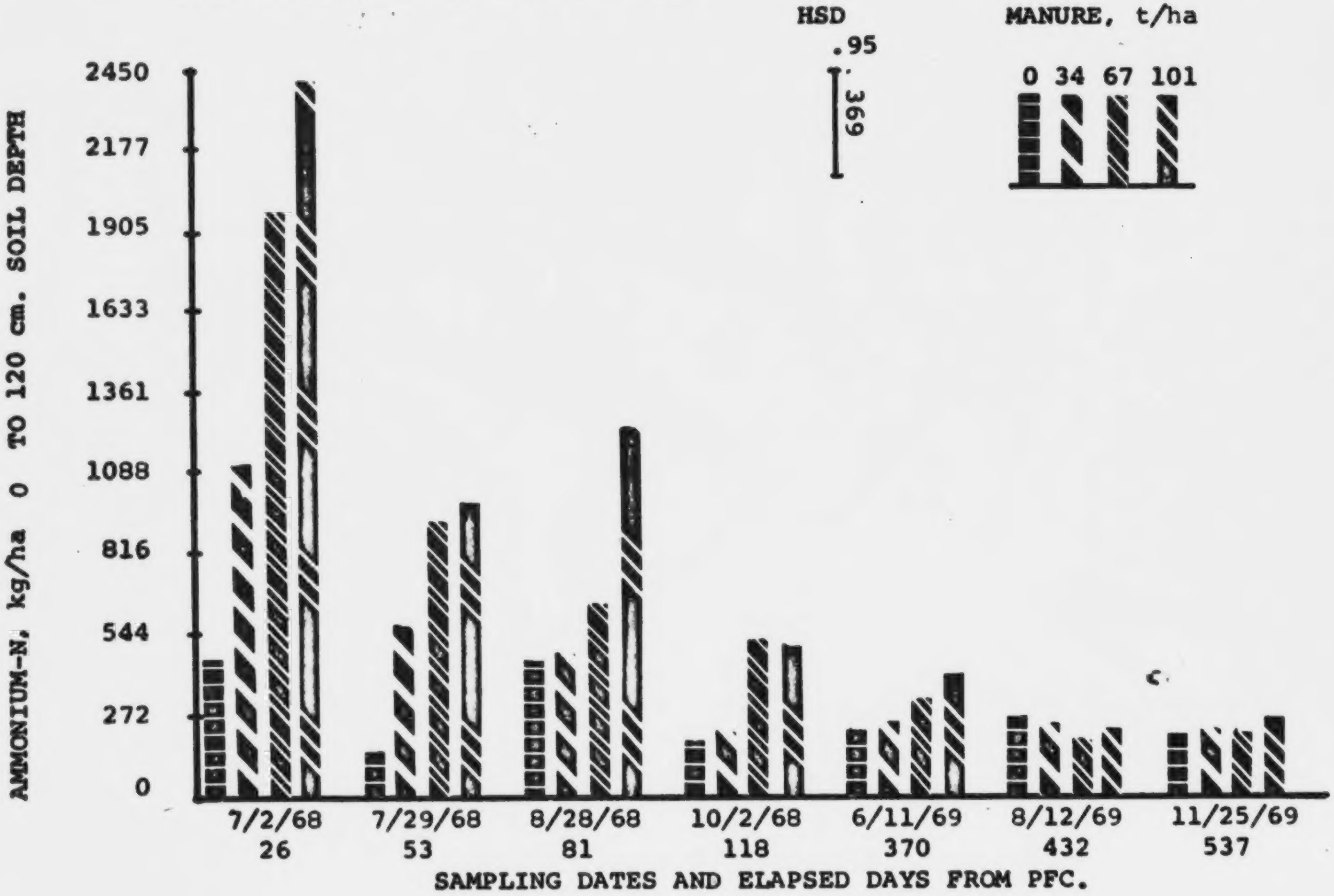
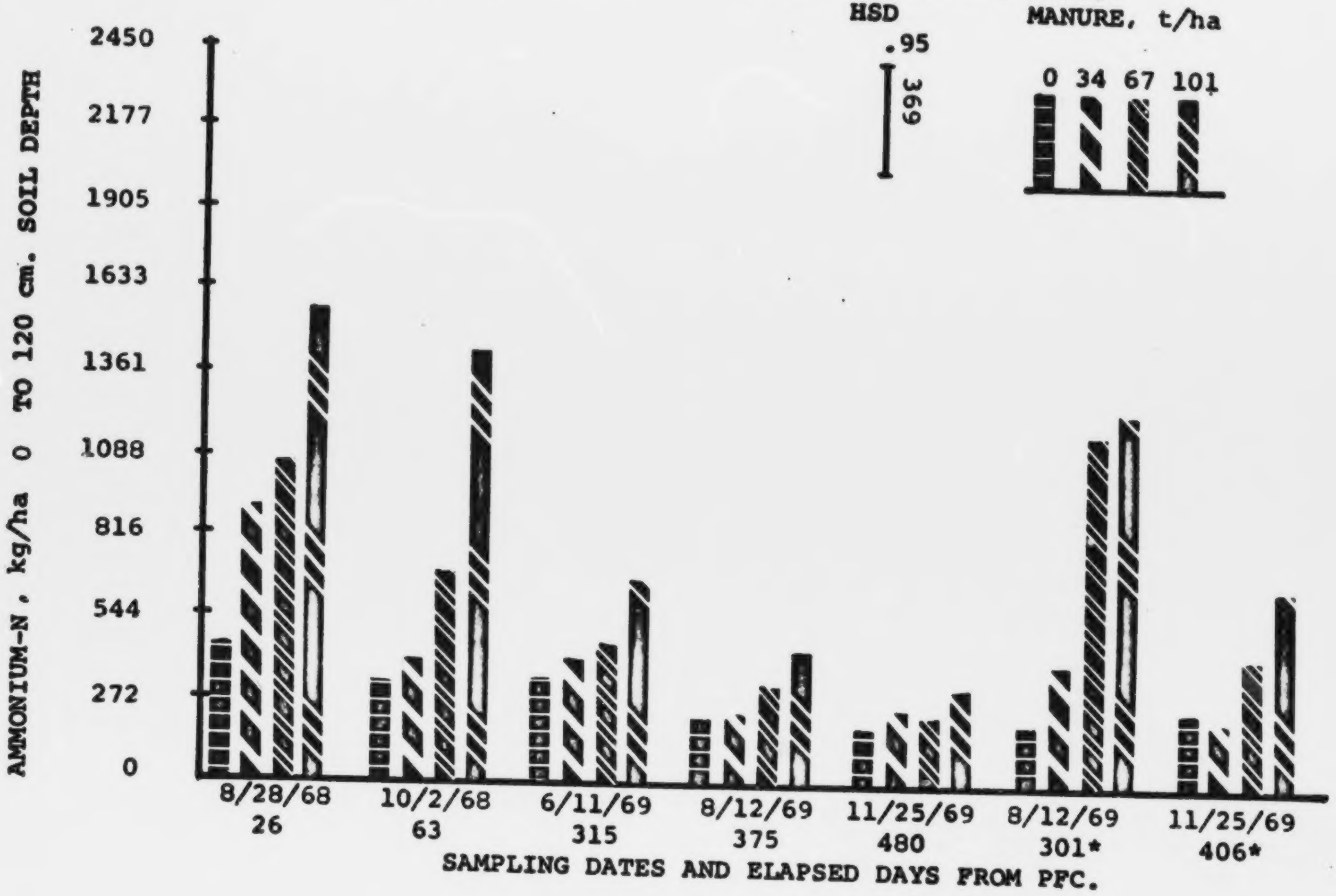


Figure 18. EXCHANGEABLE AMMONIUM-N : SUMMED FOR THE 0 TO 120 cm. SOIL DEPTH (2PFC ON AUGUST 12, 1968 AND 3PFC* ON OCTOBER 15, 1968).



ANIONS EXTRACTABLE FROM THE SOIL

The anions nitrate, chloride, and sulfate are not generally retained in the soils in the humid regions. These anions are quite soluble in water, and therefore, the amounts extractable are related to: 1) the amounts added to the soil, 2) the soil water content, and 3) the volume of water that has percolated through the soil. The behavior of phosphate is much different. Phosphate combines chemically with iron, aluminum, and calcium to form extremely insoluble chemical compounds, i.e. phosphate fixation. Phosphate mobility has been demonstrated to be very small when added to the soil in conventional agricultural amounts.

Water Extractable Nitrate-Nitrogen: Distribution in the Soil Profile.

The distribution of water extractable NO_3-N in the 0 to 120 cm depth soil profile is shown in Figure 19. The amount of poultry manure applied determined the total nitrogen introduced into the soil and the total NO_3-N that was ultimately released. This was, however, not a simple relationship. Up to 53 days after the June 6 manure application (1PFC), the 34 t/ha manure treatment released more NO_3-N than the 67 and 101 t/ha treatments. In this period no measurable leaching losses of NO_3-N had occurred. For the August 2 manure application (2PFC) the 34 t/ha treatment also released in 26 days more NO_3-N than both the 67 and 101 t/ha treatments (Figure 20). These observations were made at the same time that the amounts of exchangeable NH_4-N were found to increase as the amounts of applied manure increased (Figures 19 and 20).

This observation leads one to suspect that a difference in nitrification rate is responsible for the lower NO_3-N found in the soil treated with the larger amounts of manure. It has been suggested that low autotrophic and high heterophic organism populations prevail during active organic matter decomposition. In the early stages of manure decomposition, the two groups of organisms compete for space, oxygen, and essential nutrients. The NH_4-N concentration will be great and nitrification will be inhibited. Since autotrophs convert NH_4-N to NO_3-N, the initial higher NH_4-N content in the soil treated with the larger amounts of poultry manure will decrease nitrification. Moreover the larger manure applications will extend the period of greater heterotroph activity. With the subsidence of heterotroph activity, autotroph activity will increase and NO_3-N will be produced.

Figure 19. DISTRIBUTION OF NITRATE-N IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC (JUNE 6, 1968).

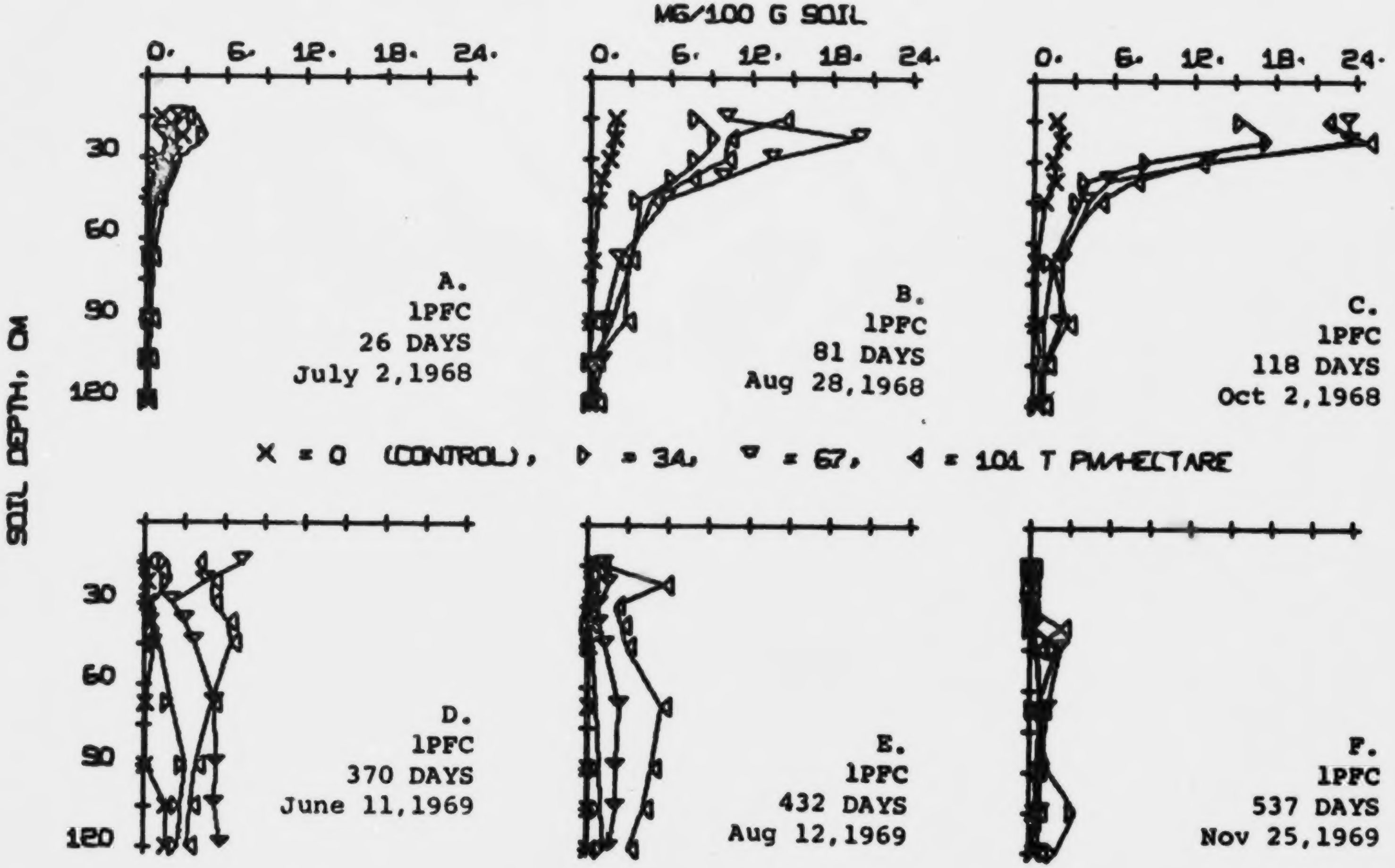


Figure 20. DISTRIBUTION OF NITRATE-N IN THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC (AUGUST 2, 1968), AND 1PFC* (JUNE 6, 1968).

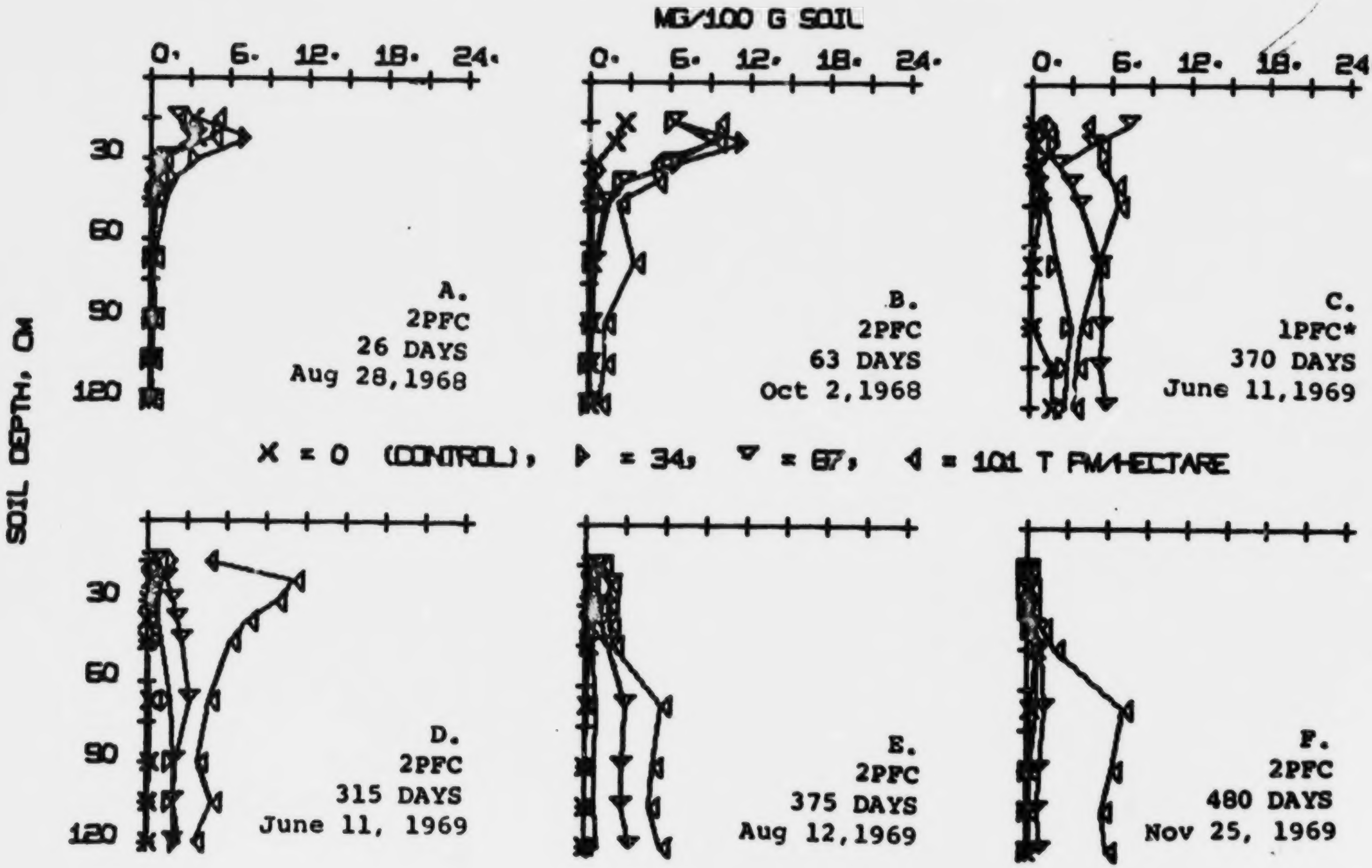
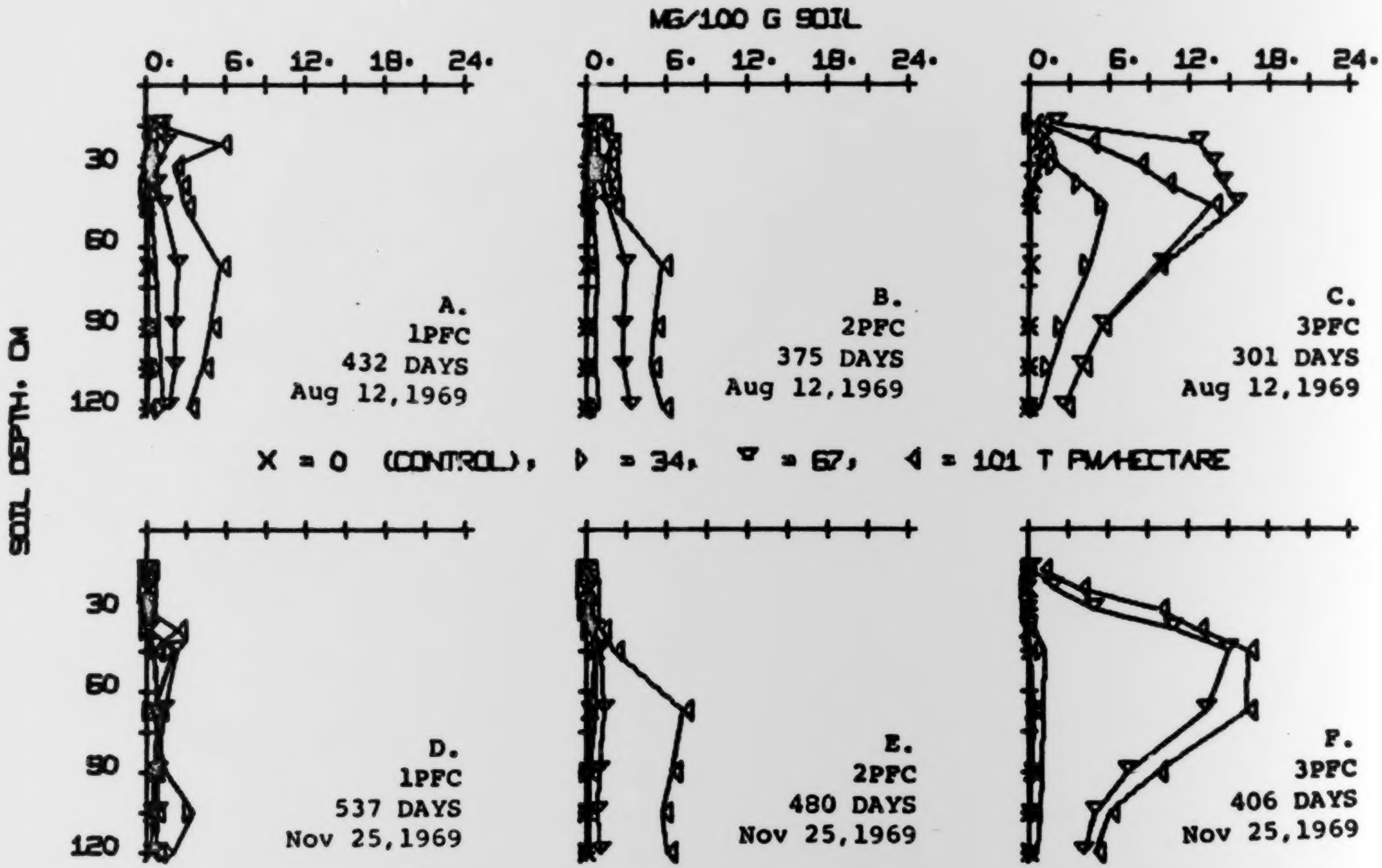


Figure 21. DISTRIBUTION OF NITRATE-N IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC AND 3PFC.



This is in agreement with the NH_4-N and NO_3-N concentrations found at the different manure applications.

After this initial period, the amount of NO_3-N increased with increasing amounts of manure. The maximum concentration, 24 mg NO_3-N/100g soil, was observed at 118 days after 1PFC (Figure 19, graph C), and this NO_3-N was still in the zone of manure application. However, increased NO_3-N was observed down to the 90 cm soil depth. After 370 days (39.31 inches rainfall) the accumulation of NO_3-N near the soil surface had disappeared, and the soil profile showed almost a uniform concentration of NO_3-N from 0 - 120 cm especially in the 101 t/ha treatment (Figure 19, graph D). At 537 elapsed days (68.91 inches rainfall) the effect of manure application on NO_3-N had almost disappeared.

The same general trend of downward movement of NO_3-N was observed for the August 2 and October 15 manure applications (Figure 20 and Figure 21). It must be noted, however, that the NO_3-N concentrations found on the 2PFC and 3PFC manure plots were much greater than those found at the same depths of the 1PFC plots (Figure 21, graphs D, E, and F). The 0 - 120 cm soil profiles on November 25 had been leached free of NO_3-N where 34 t/ha of manure had been applied. The increased NO_3-N concentration of the October 15 manure applications of 67 and 101 t/ha (3PFC) is due to the immobilization and subsequent mineralization of nitrogen. This observed high NO_3-N concentration 406 days (51.79 inches rainfall) after the manure applications indicates a considerable time-lag in the appearance of NO_3-N when the manure applications are made in late autumn.

Water Extractable Nitrate-Nitrogen: Summed for the Soil Profile Studied.

The summed water extractable NO_3-N values for the 0 - 120 cm soil profile are shown in Figure 22. They show the net result of NO_3-N released from the poultry manure and the NO_3-N lost by leaching from the June 6 manure applications. The NO_3-N content of the soil profile increased up to 118 days after application and then decreased with elapsed days. Prior to 118 days NO_3-N release exceeded leaching losses, whereas, the opposite is true from 370 days after manure application.

At 26 elapsed days the 34 t/ha treatment had released more NO_3-N than both the 67 and 101 t/ha treatments. At 53 elapsed days there is also an inverse relationship of NO_3-N released between the 34, 67, and 101 t/ha manure treatments. However, at 432 elapsed days the amount of NO_3-N in the soil profile was

Figure 22. NITRATE-N INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) SAMPLED ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

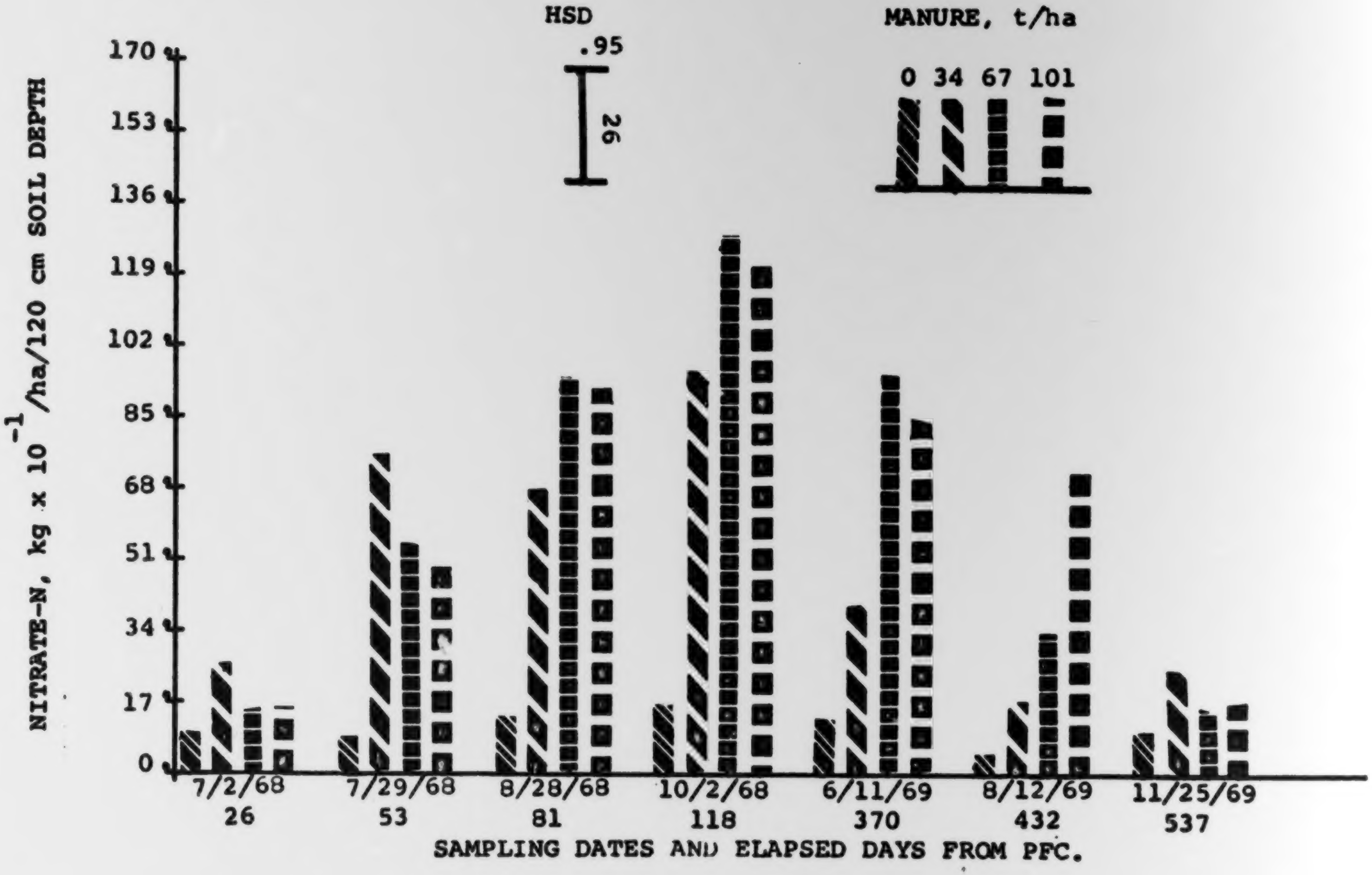
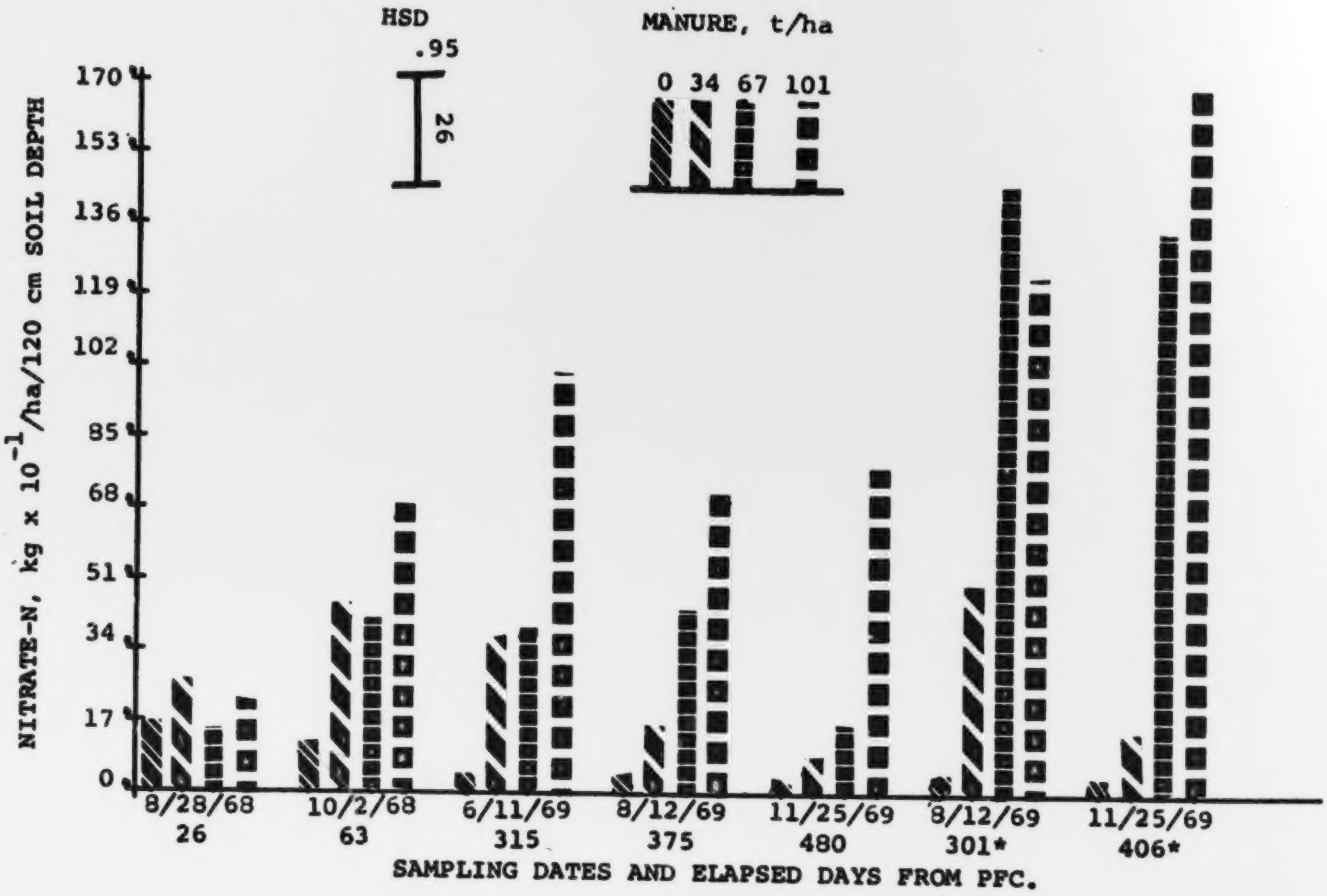


Figure 23. NITRATE-N INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) FROM 2PFC (AUGUST 2, 1968) AND 3PFC*(OCTOBER 15, 1968).



directly proportional to the amount of manure applied.

Figure 23 shows the summed NO_3-N in the 0 - 120 cm soil profile for the August 2 and October 15 manure applications (2PFC and 3PFC, respectively). Generally, the same general increase and subsequent decrease of NO_3-N was observed for 2PFC as for 1PFC. However, for the October 15 manure application (3PFC), the summed NO_3-N as observed at 406 elapsed days was still very large. The control profile contained 34.0 kg NO_3-N and the 34, 67, 101 t/ha manure treatments contained 149.2, 1330.7, and 1697.2 kg NO_3-N/ha, respectively. The amounts of NO_3-N for the 67 and 101 t manure treatments demonstrate the effectiveness of the nitrogen immobilization - mineralization cycle for delaying the appearance of water extractable NO_3-N.

Water Extractable Chloride: Distribution in the Soil Profile.

The distribution of water extractable Cl from the 0 - 120 cm soil profile depth is shown in Figure 24. Downward movement of Cl was already evident 26 days after manure application. An increase in Cl concentration from the 101 t/ha manure application was noted at the 90 cm depth after a total of 7.21 inches of rainfall had been received, however the highest concentration was still in the zone of manure application. Up to 118 days (17.12 inches rainfall) the concentration of Cl decreased as depth increased, being close to zero at the 120 cm depth. The concentrations of Cl above the 105 cm depth increased as the amount of applied manure increased. By 432 days (Figure 24, graph E) the Cl concentration from 0-45 cm depth no longer showed differences between the control and the 34 and 67 t/ha manure treatments. Rainfall had been 57.54 inches. At 537 days after the June 6 manure applications (68.91 inches rainfall) the effect of manure treatment on the Cl concentration had disappeared throughout the profile except for the 101 t at depths below 60 cm.

Generally the same observations of Cl downward movement were true for all times of application of poultry manure (Figures 25 and 26). At 315 days after the August 2 manure application (2PFC), the 30.23 inches of rainfall had decreased the Cl concentration in the application zone to near zero, however below 60 cm depth the Cl concentration remained about constant down to 120 cm (Figure 25, graph D).

Figure 24. DISTRIBUTION OF CHLORIDE IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC (JUNE 6, 1968).

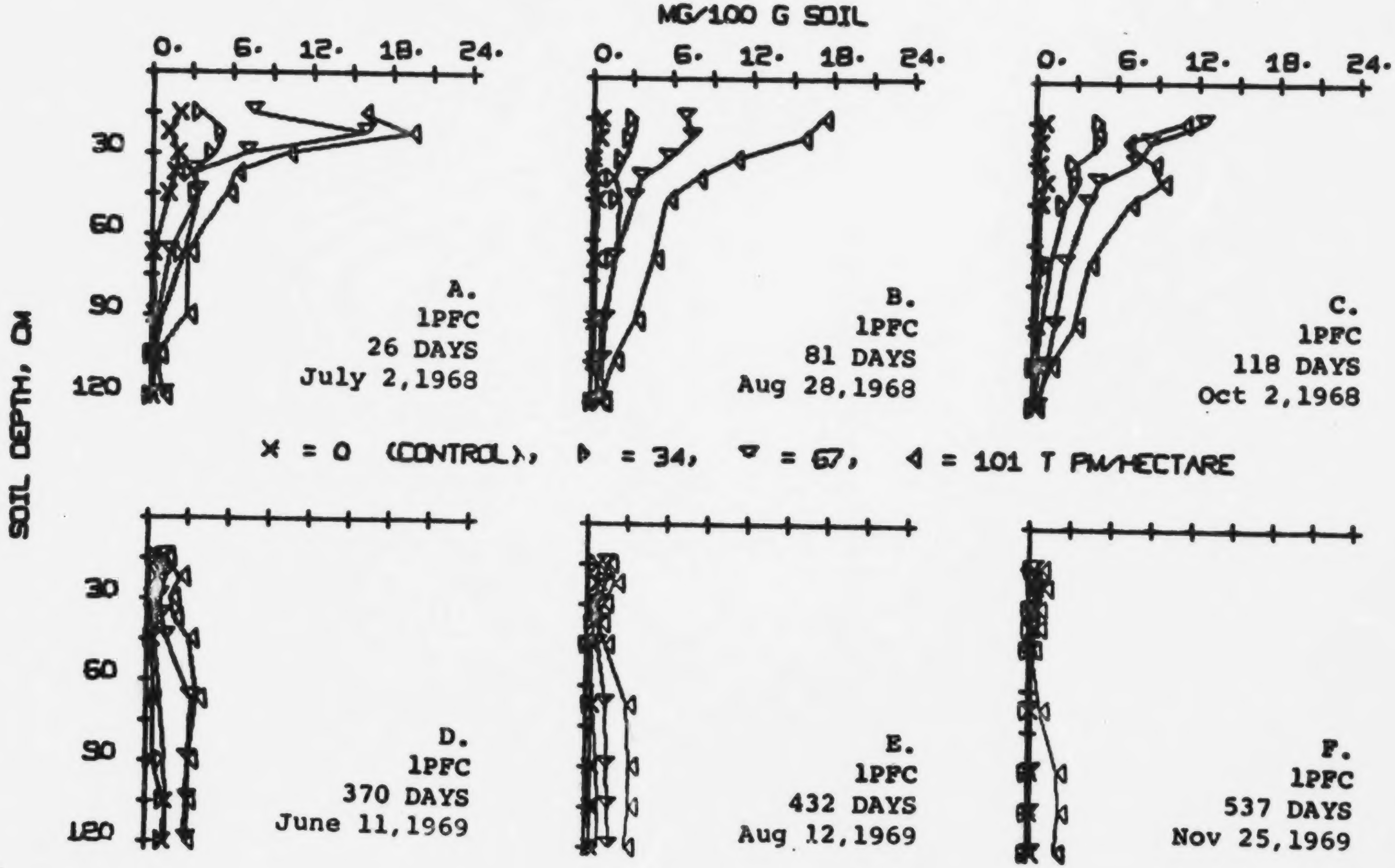


Figure 25. DISTRIBUTION OF CHLORIDE IN THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC (AUGUST 2, 1968), AND 1PFC* (JUNE 6, 1968).

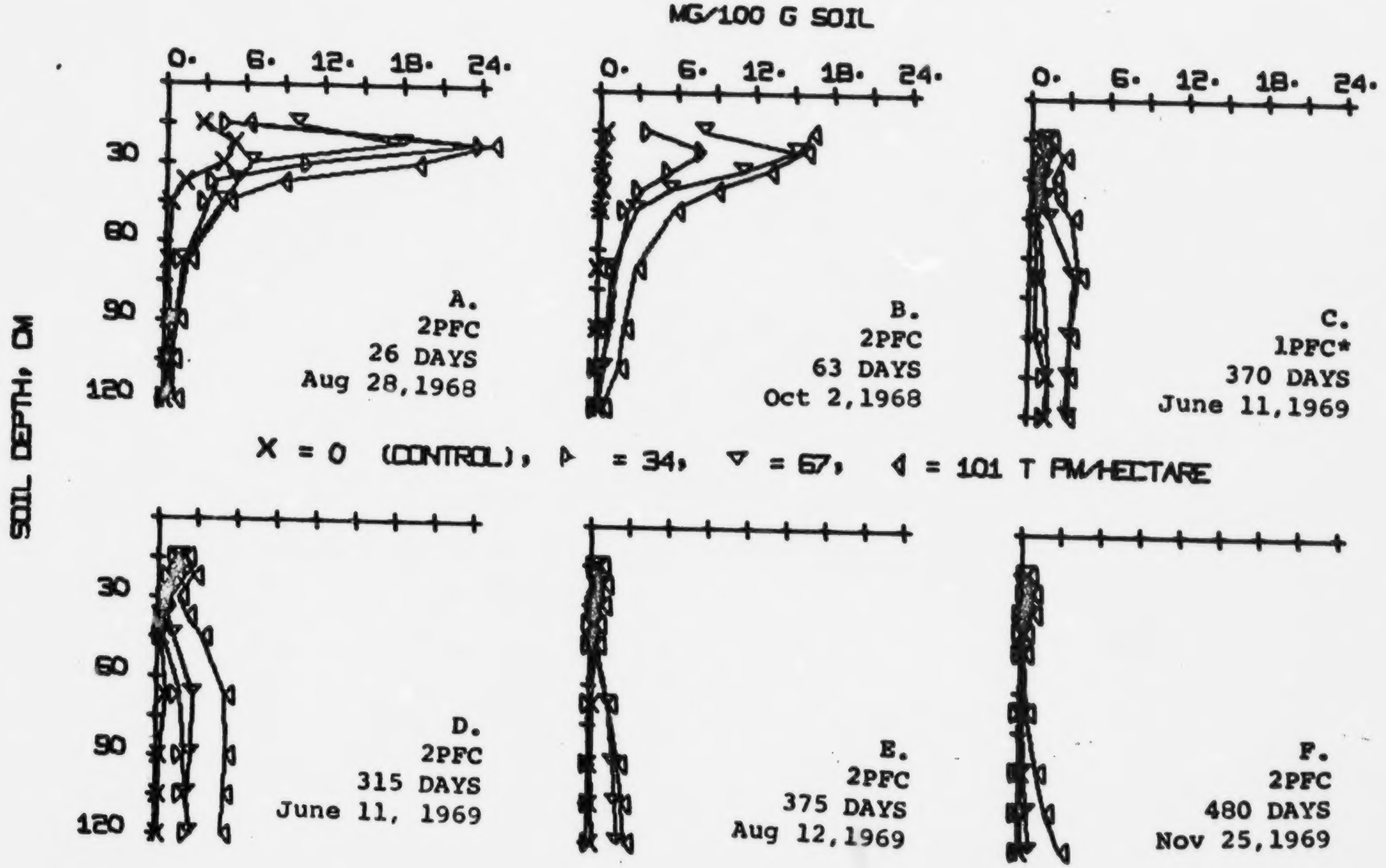
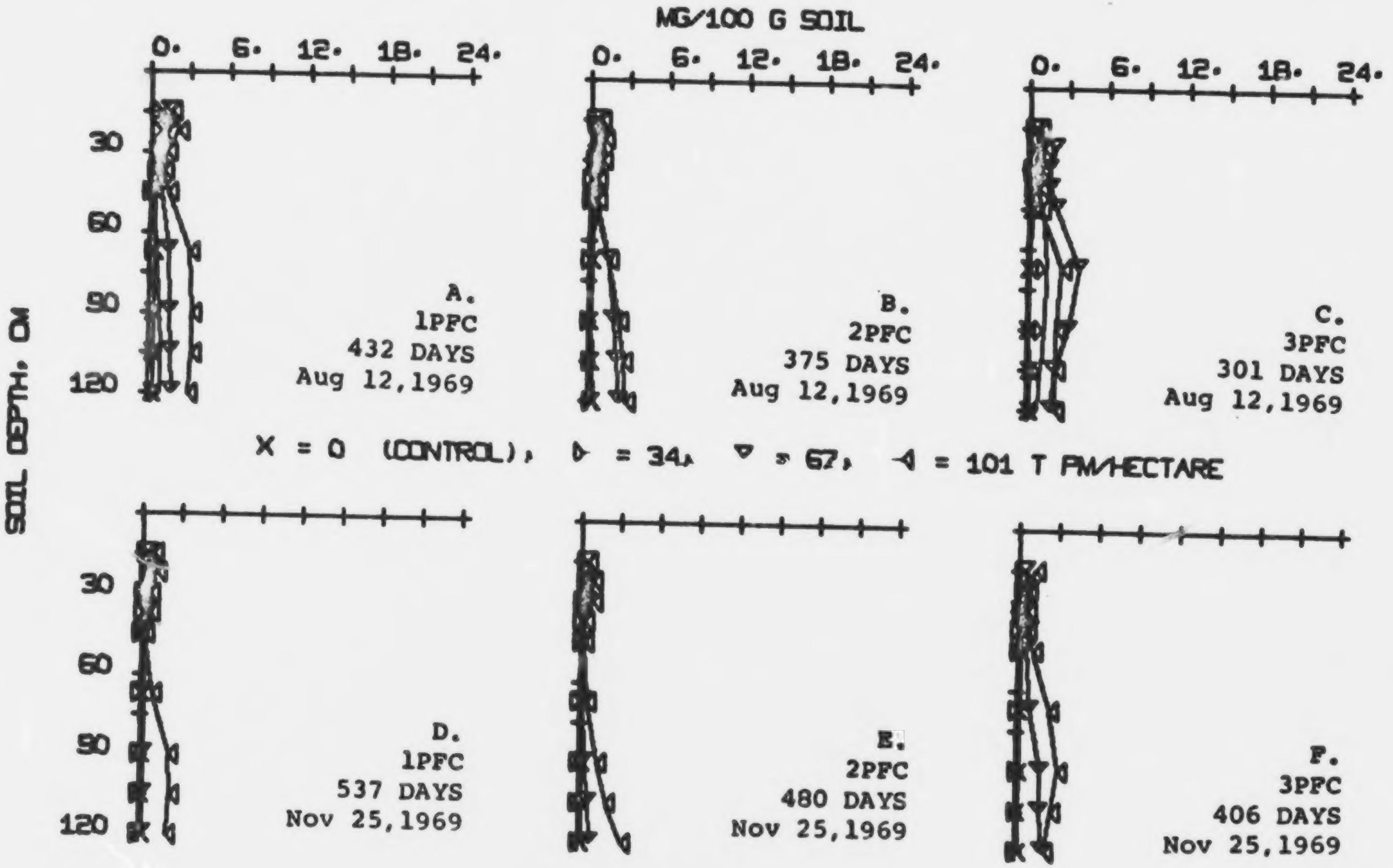


Figure 26. DISTRIBUTION OF CHLORIDE IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC AND 3PFC.



Water Extractable Chloride: Summed for the Soil Profile Studied.

The summed water extractable Cl values for the 0-120 cm soil profile are shown in Figure 27 for the June 6 (1PFC) manure applications. The total Cl content increased as the amount of applied manure was increased on specific sampling dates. The total Cl generally decreased as the elapsed days increased because of leaching losses. As elapsed days increased, the percolation volume increased due to greater precipitation. Since the depth to which Cl moves is proportional to the percolation volume, the higher concentration of chloride in the 0-120 cm soil depth had almost disappeared 537 days and 68.91 inches of rainfall (Figure 27). At 81 days and 15.82 inches of rainfall, the Cl content in the 101 t/ha treatment was 1200 kg/ha/120 cm soil depth. At 537 days the Cl content had been lowered by leaching to about 260 kg/ha/120 cm soil depth.

In Figure 28 the Cl content on the August 2 manure applications (2PFC) was 750 kg/ha at 315 elapsed days for the 101 t/ha treatment. For the October 15 manure applications (3PFC) the 101 t/ha treatment contained 320 kg Cl/ha after 301 elapsed days. This illustrates greater leaching intensity which prevails during the winter and spring as compared to the summer months.

Water Extractable Sulfate: Distribution in the Soil Profile.

The distribution of water extractable SO_4 in the 0-120 cm soil profile is shown in Figure 29 for the June 6 manure applications (1PFC). Examination of the control shows a high concentration of SO_4 in the subsoil prior to the application of poultry manure - about 9 mg SO_4/100g soil at the beginning and this remained practically unchanged throughout the duration of the experiment. In the manure treatments the SO_4 concentration increased as the amounts of manure increased, however this increase was observed only for the 0 to 45 cm soil depth. In fact it seems that in general the SO_4 concentration in the 60 to 120 cm depth decreased as the amount of poultry manure increased.

Figures 30 and 31 show the SO_4 distribution for the August 2 and the October 15 manure applications. In general the SO_4 concentration initially was increased in the manure application zone and the SO_4 concentration in the 30 to 60 cm depth increased with amount of manure and with elapsed days. SO_4 concentration in the 60 to 120 cm depth decreased also as in the June 6 manure application plots.

Figure 27. CHLORIDE INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) SAMPLED ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

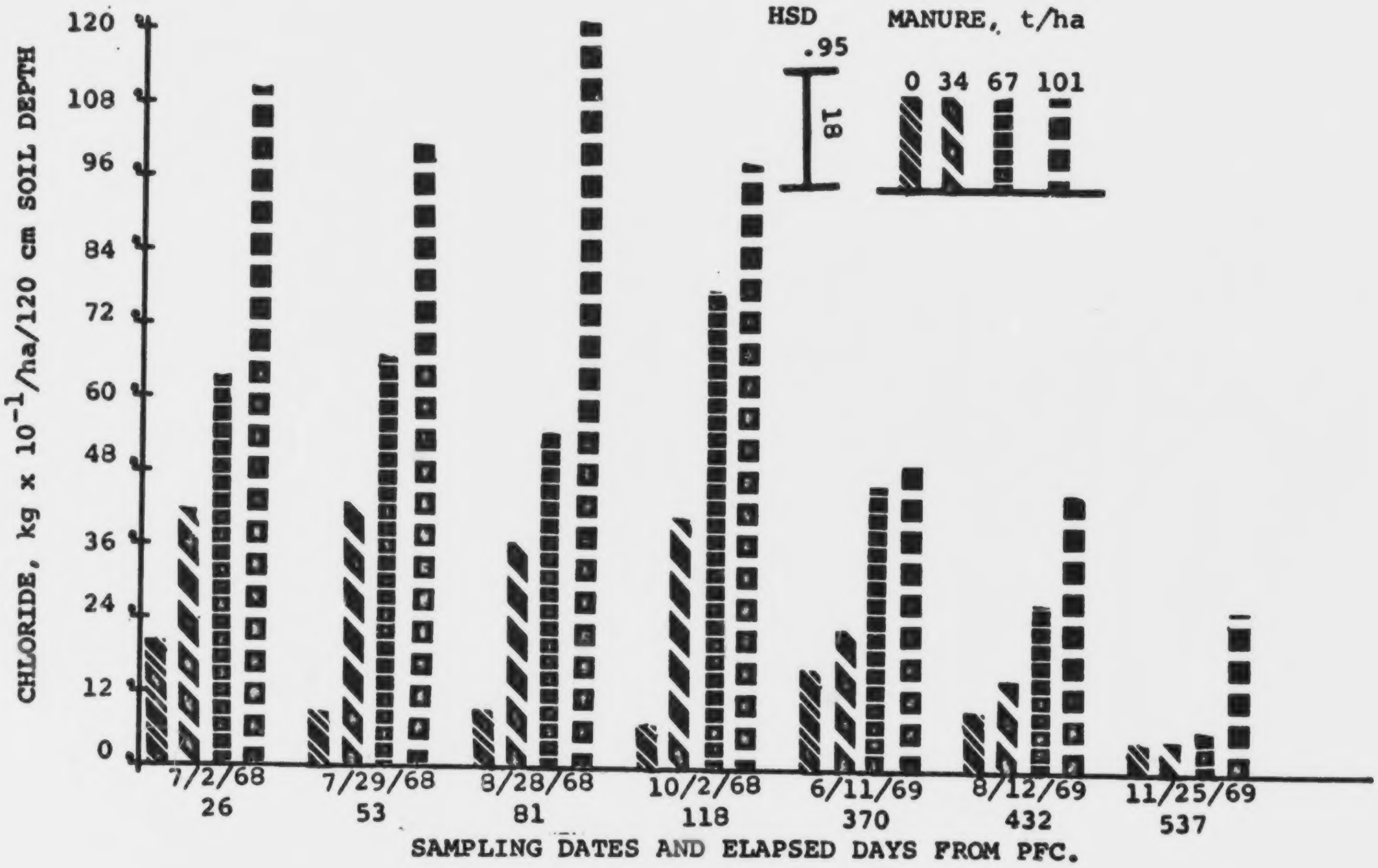


Figure 28. CHLORIDE INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) FROM 2PFC (AUGUST 2, 1968) AND 3PFC* (OCTOBER 15, 1968).

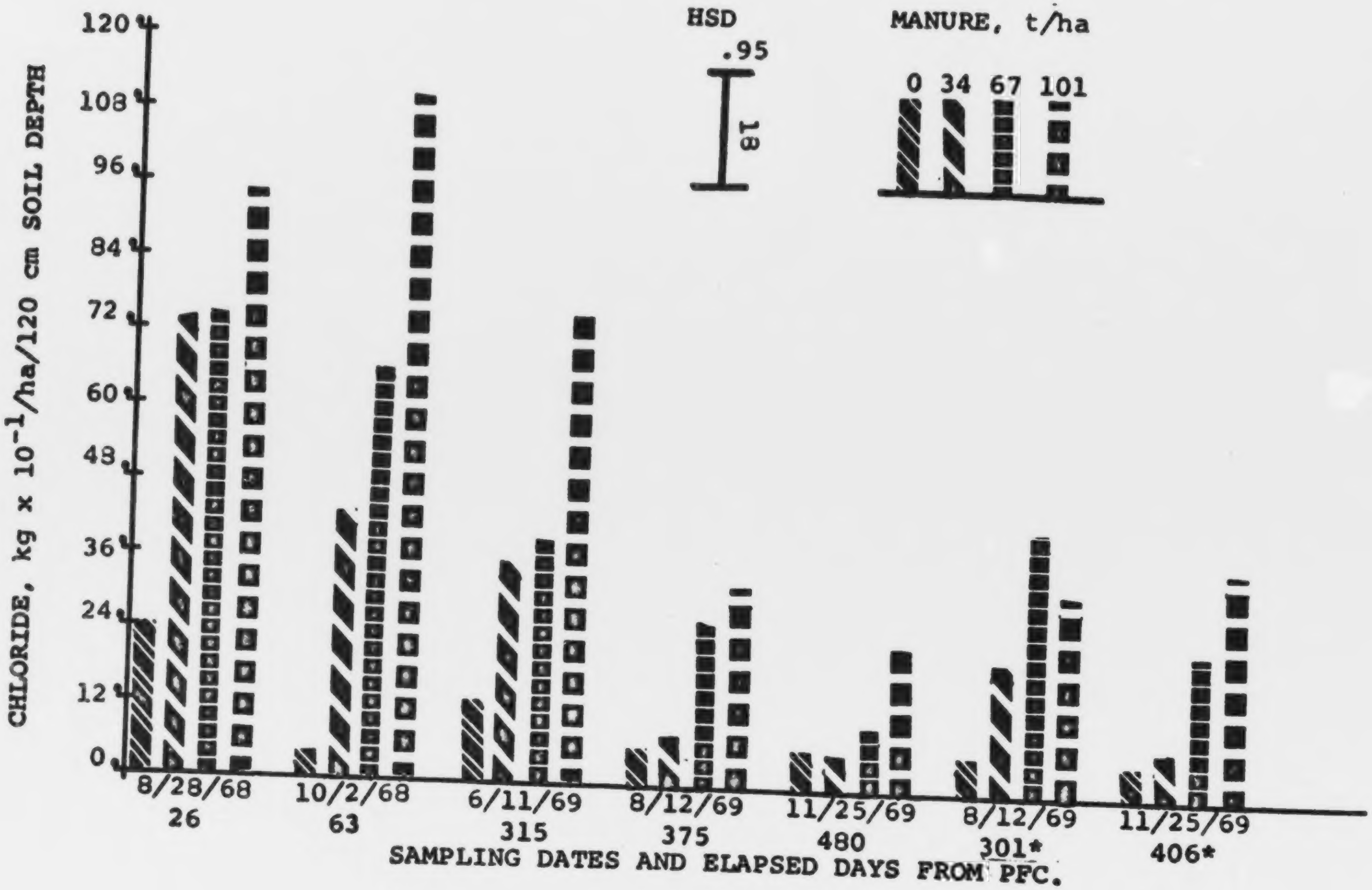


Figure 29. DISTRIBUTION OF SULFATE IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC (JUNE 6, 1968).

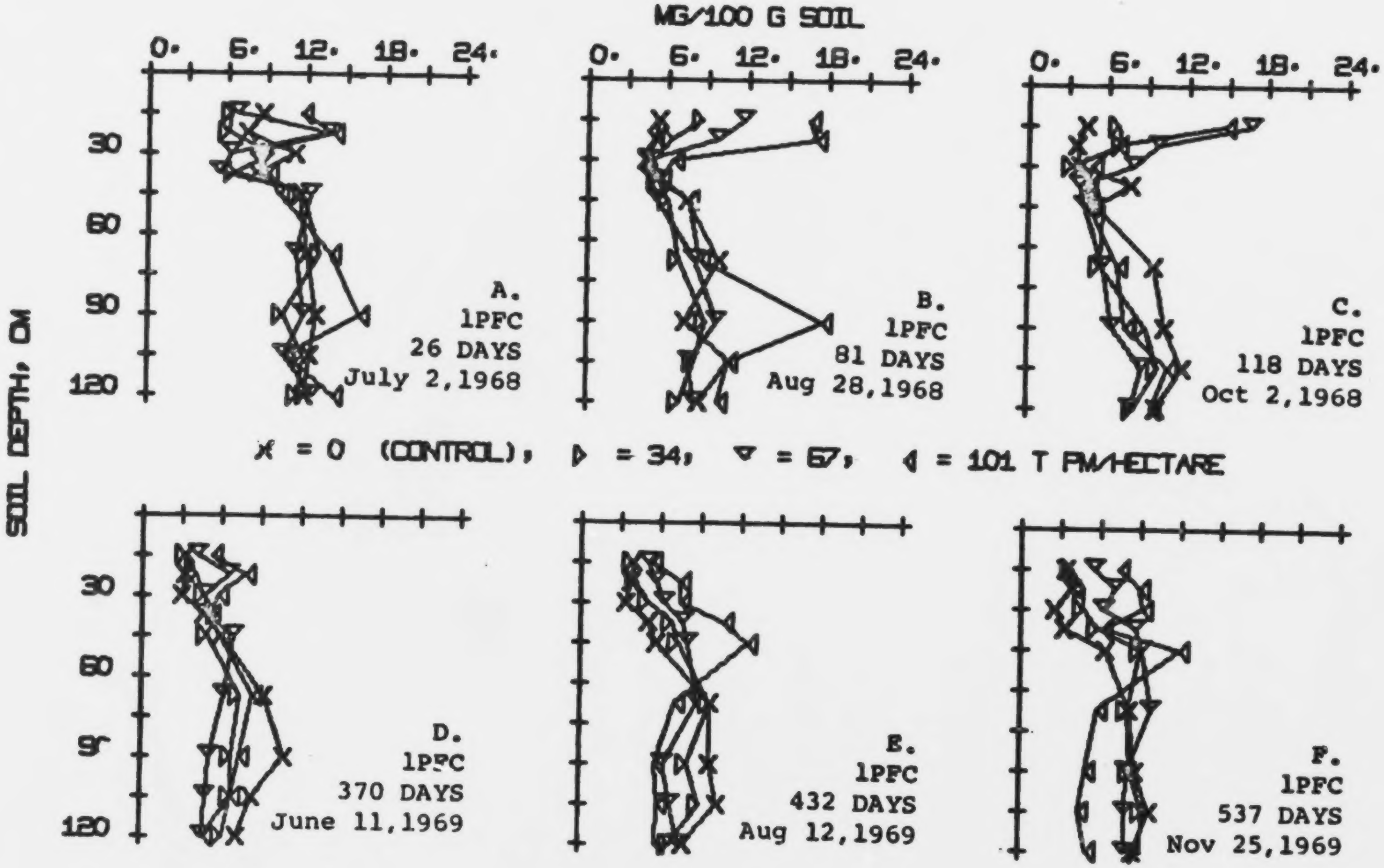


Figure 30. DISTRIBUTION OF SULFATE IN THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC (AUGUST 2, 1968), AND 1PFC* (JUNE 6, 1968).

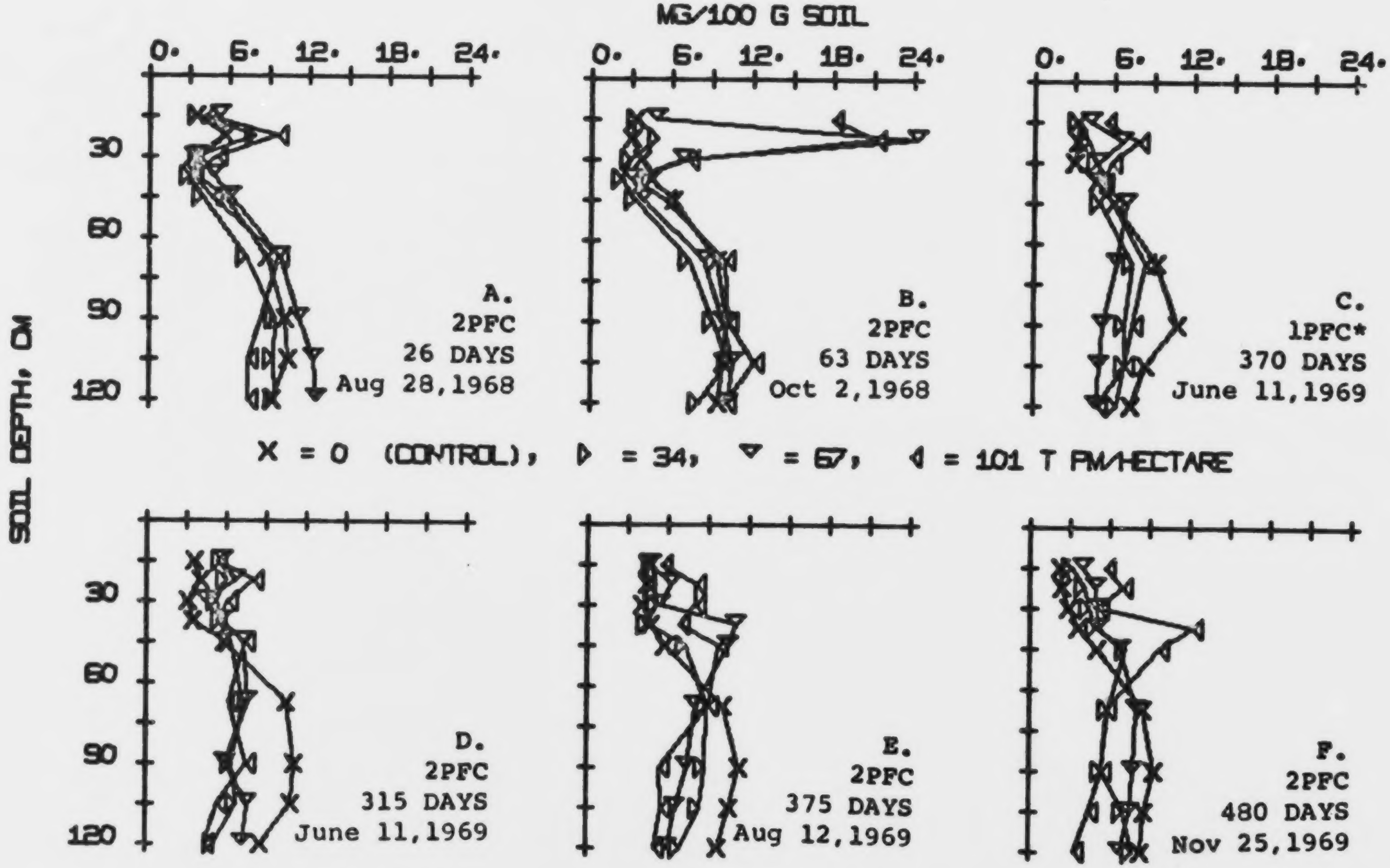
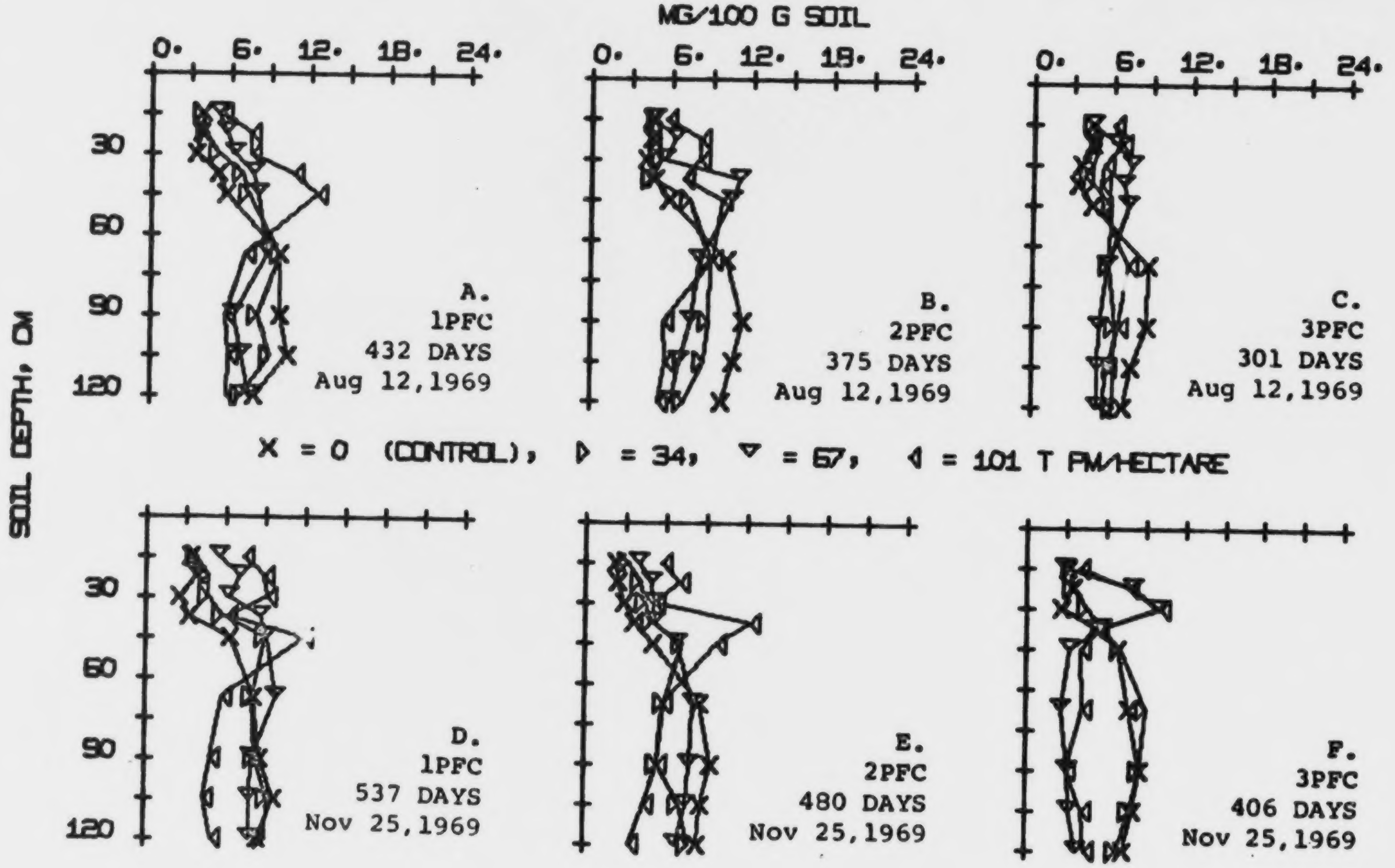


Figure 31. DISTRIBUTION OF SULFATE IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC AND 3PFC.



Water Extractable Sulfate: Summed for the Soil Profile Studied.

The total water extractable SO_4 content of the 0-120 cm soil profile generally decreased as elapsed days increased (Figures 32 and 33). This decrease is due to leaching losses in the drainage water. Although appreciable quantities of SO_4 remain in the soil profile at the end of the experiment and SO_4 content does not appear to be increased with increased amounts of manure, the SO_4 distribution curves showed increased SO_4 content in the 0 to 60 cm soil depth and decreased SO_4 content in the 60 to 120 cm depth. The gains in the shallower soil depths appear to be offset by the losses in the deeper depths of the soil. These observations apply for all three application dates of poultry manure.

Water Extractable Phosphate: Distribution in the Soil Profile.

The distribution of water extractable PO_4 in the 0-120 cm soil profile is shown in Figures 34, 35, and 36. The water soluble PO_4 was concentrated at about 22 cm depth. This is the zone of manure application and very little or no downward movement was detected. The PO_4 concentration increased with increased amounts of poultry manure. Generally, PO_4 concentration increased with increased elapsed days; this was most evident in the 101 t/ha manure treatment. The behavior of the water extractable PO_4 with elapsed days may be due to the increased mineralization of organic forms of phosphorus. It must be noted that high levels of water extractable PO_4 were not maintained. In the June 6 application, the 101 t/ha manure treatment showed over 9 mg of PO_4/100g soil at 118 elapsed days. However at 370 elapsed days the concentration had decreased to 6 mg/100g at the same depth. At 432 days the PO_4 concentration was 12 mg/100g soil at the 22.5 cm depth and at 537 days it had decreased to less than 9.

The downward movement of PO_4 as measured by water extractable PO_4 was very small if it occurred at all. Very little water extractable PO_4 was found below 30 cm depths and usually none was found at 45 cm and below.

Water Extractable Phosphate: Summed for the Soil Profile Studied.

The summed water extractable PO_4 values for the 0 to 120 cm soil profile are shown in Figures 37 and 38. These values indicate that only a small percentage of the total applied phosphorus could be measured in water-soluble forms. Since it

Figure 32. SULFATE INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) SAMPLED ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

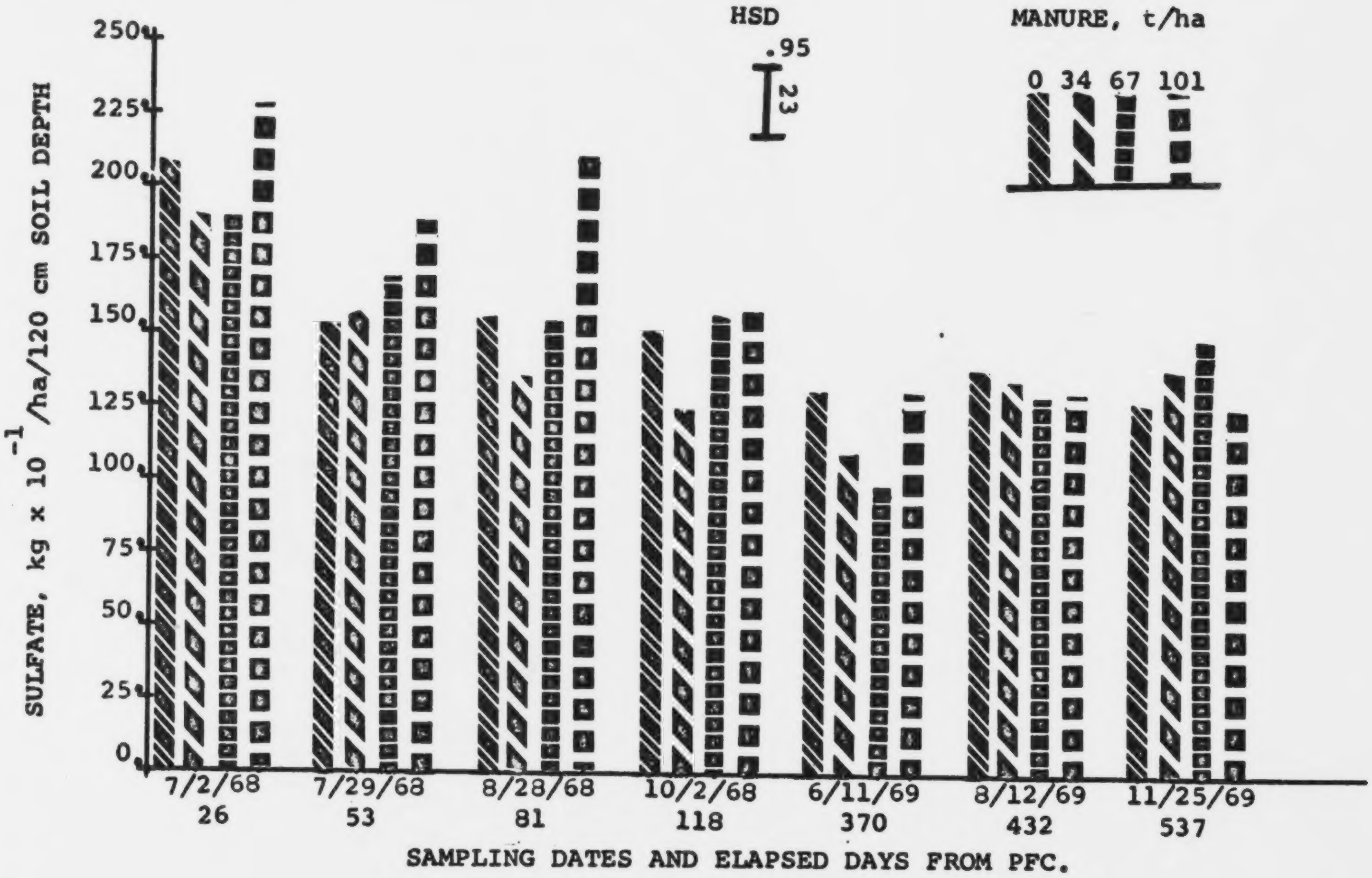


Figure 33. SULFATE INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) FROM 2PFC (AUGUST 2, 1968) AND 3PFC*(OCTOBER 15, 1968).

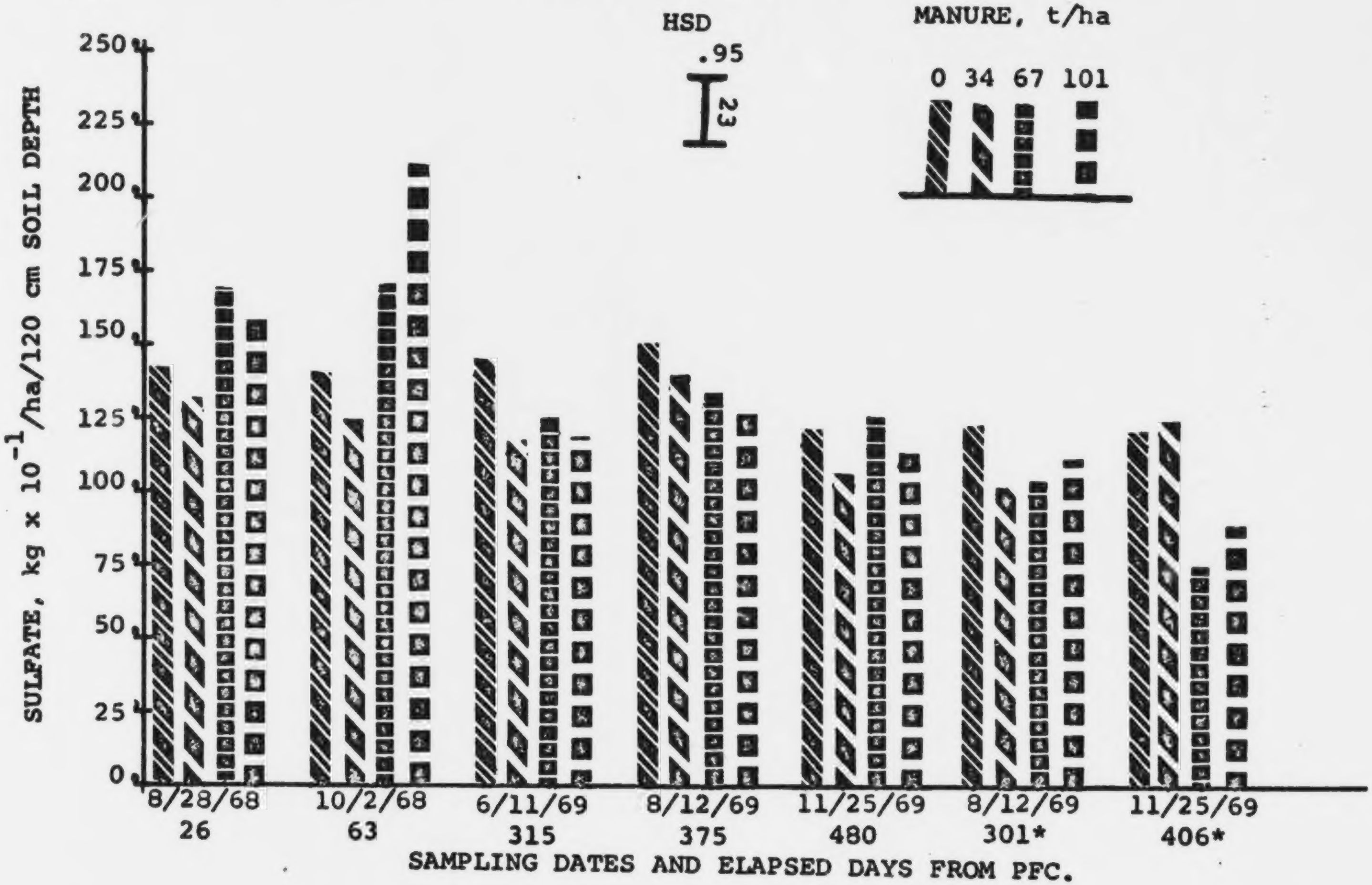


Figure 34. DISTRIBUTION OF WATER SOLUBLE PHOSPHATE IN THE SOIL PROFILE SAMPLED ON FOUR DATES AFTER 1PFC (JUNE 6, 1968).

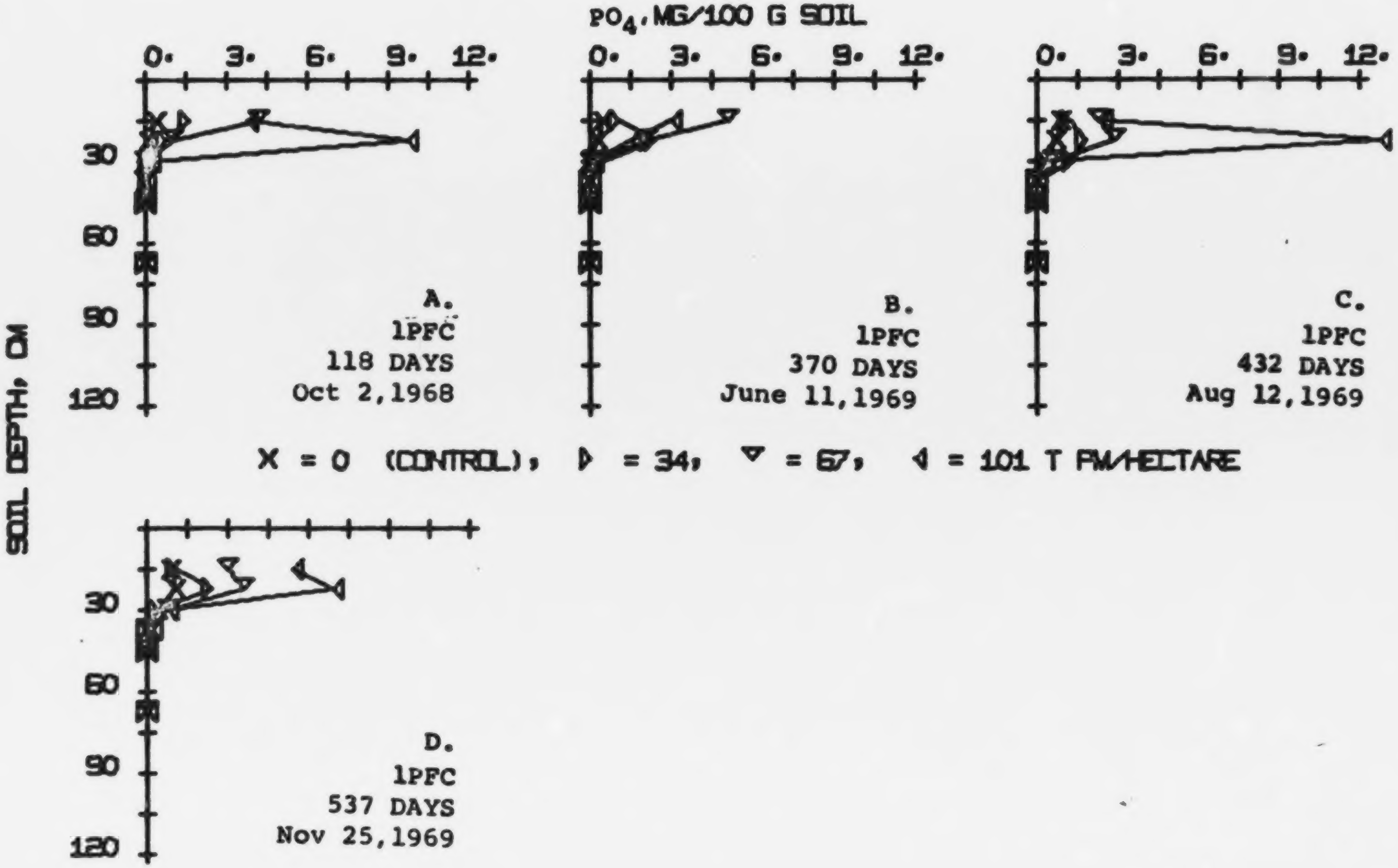


Figure 35. DISTRIBUTION OF WATER SOLUBLE PHOSPHATE IN THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC (AUGUST 2, 1968), AND 1PFC* (JUNE 6, 1968).

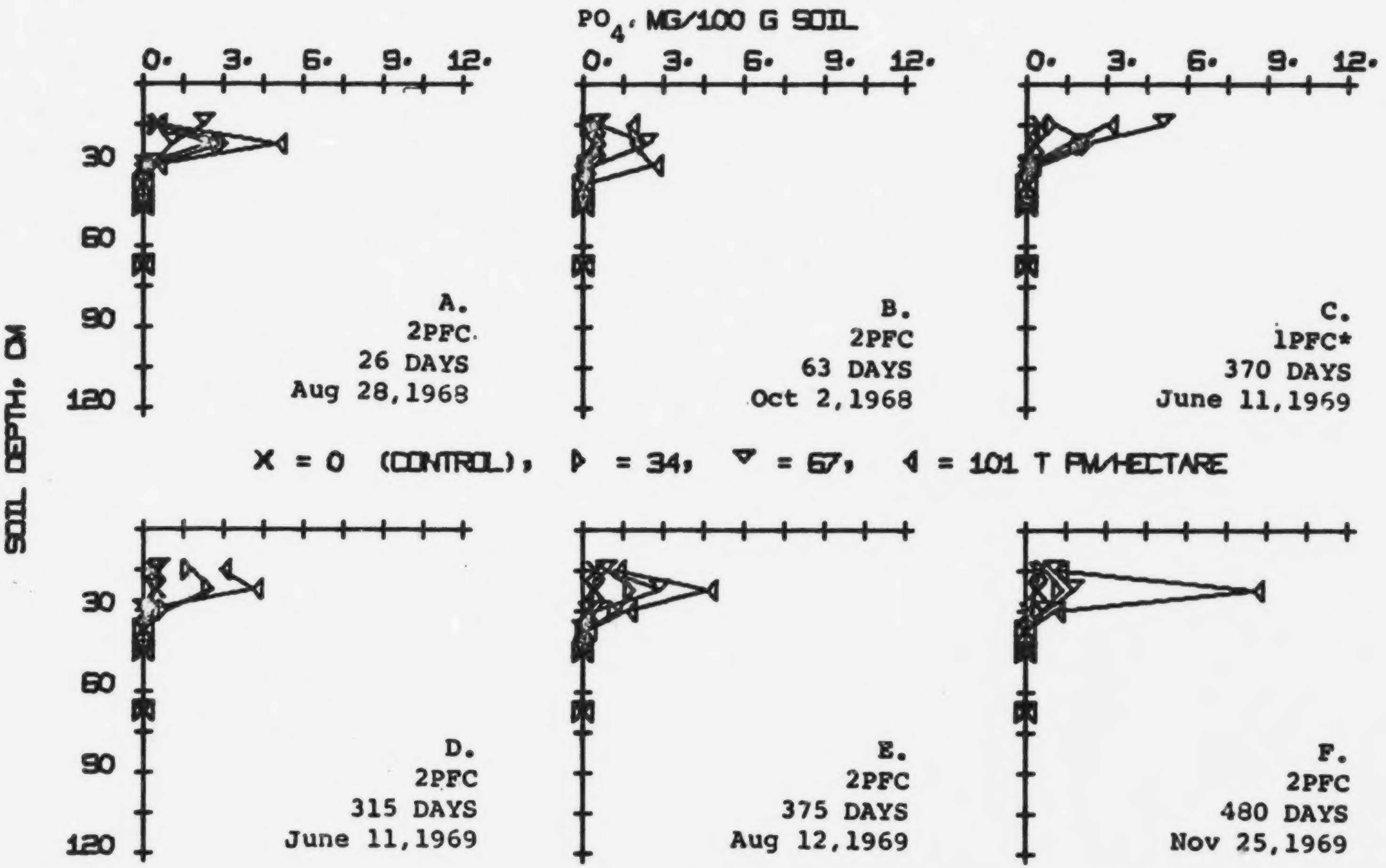
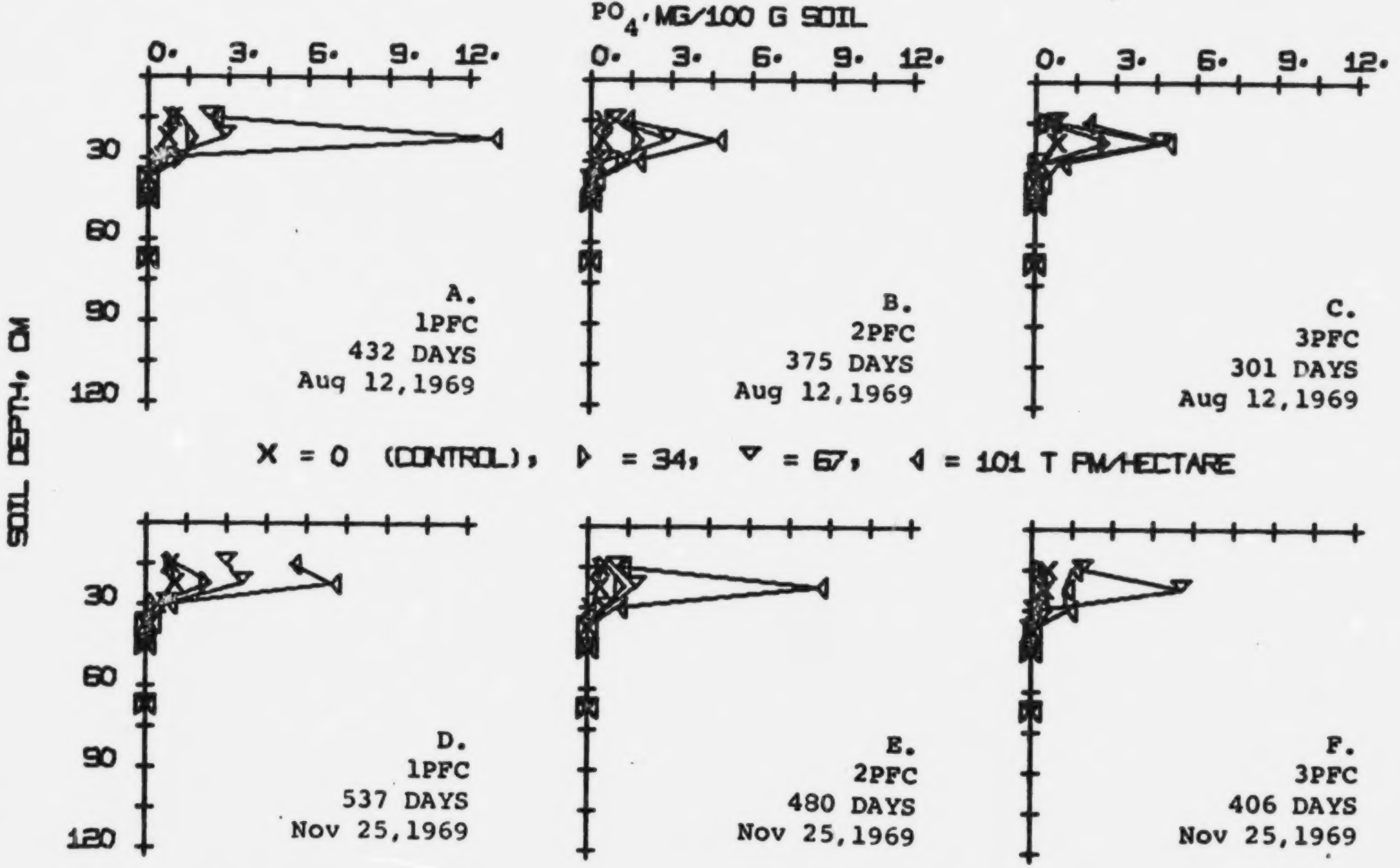


Figure 36. DISTRIBUTION OF WATER SOLUBLE PHOSPHATE IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC AND 3PFC.



A.
1PFC
432 DAYS
Aug 12,1969

B.
2PFC
375 DAYS
Aug 12,1969

C.
3PFC
301 DAYS
Aug 12,1969

D.
1PFC
537 DAYS
Nov 25,1969

E.
2PFC
480 DAYS
Nov 25,1969

F.
3PFC
406 DAYS
Nov 25,1969

Figure 37. PHOSPHATE-P, WATER SOLUBLE, INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) SAMPLED ON FOUR DATES AFTER 1PFC (JUNE 6, 1968).

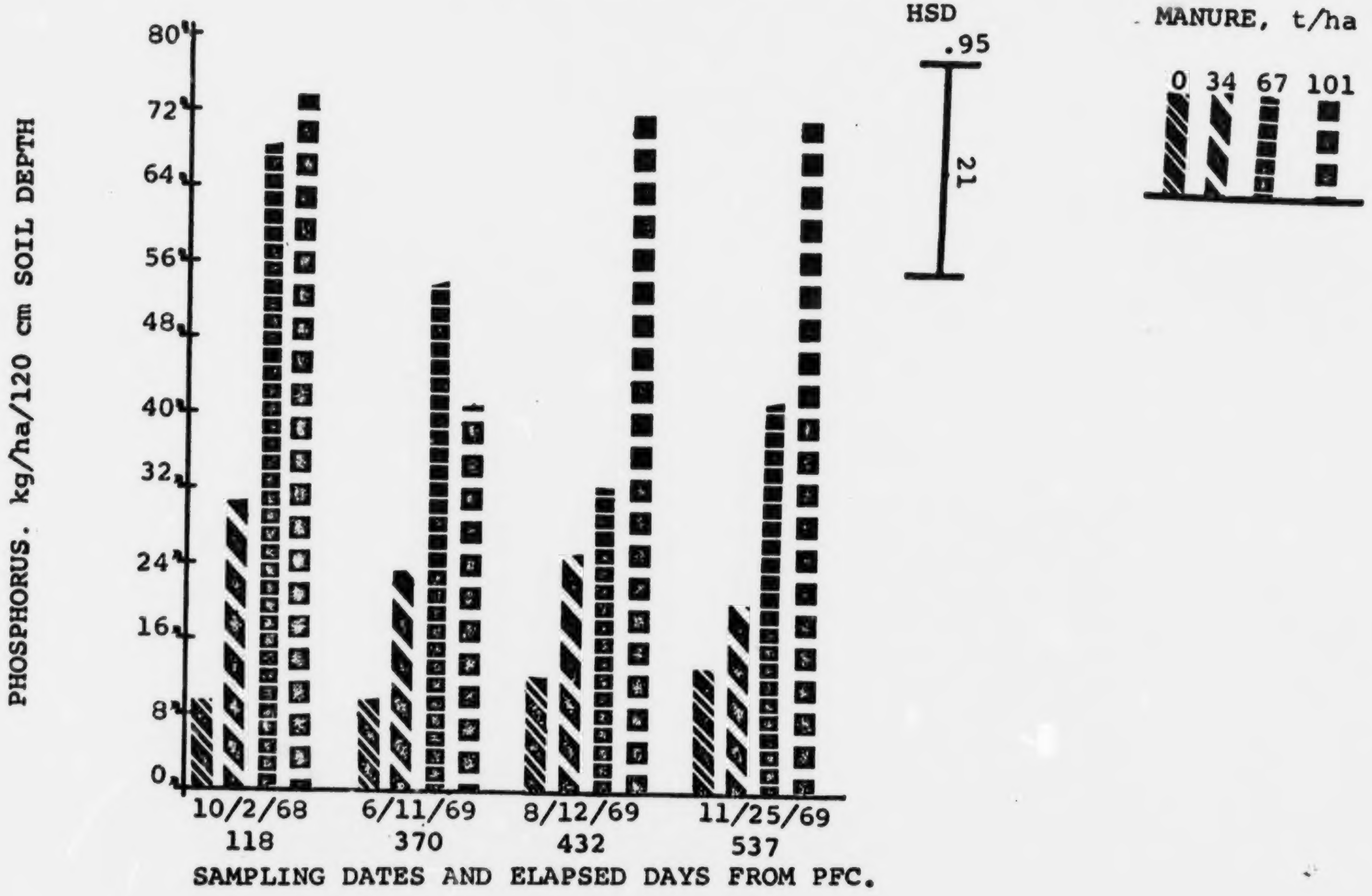
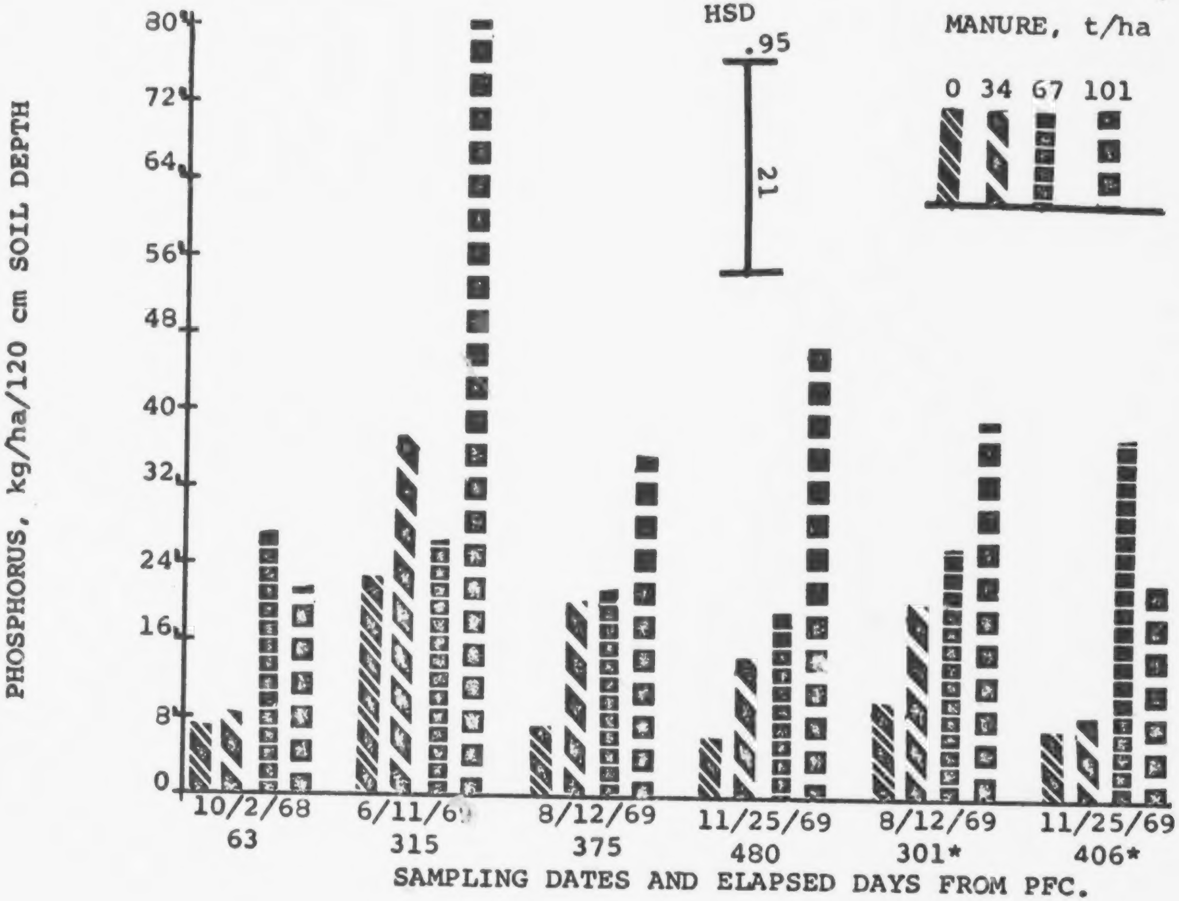


Figure 38. PHOSPHATE-P, WATER SOLUBLE, INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) FROM 2PFC (AUGUST 2, 1968) AND 3PFC* (OCTOBER 15, 1968).



is the water-soluble form of phosphorus which can move in the percolation water and no such form was detected below the 45 cm depth, there is very little chance of underground water pollution by phosphorus in the percolation water.

Bray Extractable Phosphate: Distribution in the Soil Profile.

The Bray extraction technique (Bray #1) removes from the soil the more readily soluble portion of each form of available soil phosphorus. The distribution of Bray PO_4 in the 0-120 cm soil profile is shown in Figures 39, 40, and 41. Throughout the experimental period, the concentration of Bray PO_4 only changed appreciably close to the zone of manure application. In this zone the PO_4 concentration increased with increasing amounts of poultry manure. It also increased with increased elapsed days. The PO_4 concentration at the 60 to 120 cm depth ranged between 0.8 and 1.5 mg/100g soil throughout the experimental period and could not be said to increase because of the application of poultry manure. This indicates that PO_4 mobility was less than 15 cm below the manure application zone.

Bray Extractable Phosphate: Summed for the Soil Profile Studied.

The summed Bray PO_4 content of the 0-120 cm soil profile generally increased with increased elapsed days (Figures 42 and 43). It also increased with increasing amounts of poultry manure applied. Although the amount of Bray PO_4 increased with increased elapsed days where manure had been applied, the control plots were quite constant in Bray PO_4 throughout the experimental period. This indicates a mineralization of the organic phosphorus forms in the manure to inorganic phosphorus forms which are termed available for plant growth. The distribution curves showed very slight downward mobility of this available PO_4.

Figure 39. DISTRIBUTION OF BRAY-PHOSPHATE IN THE SOIL PROFILE SAMPLED ON SIX DATES AFTER 1PFC (JUNE 6, 1968).

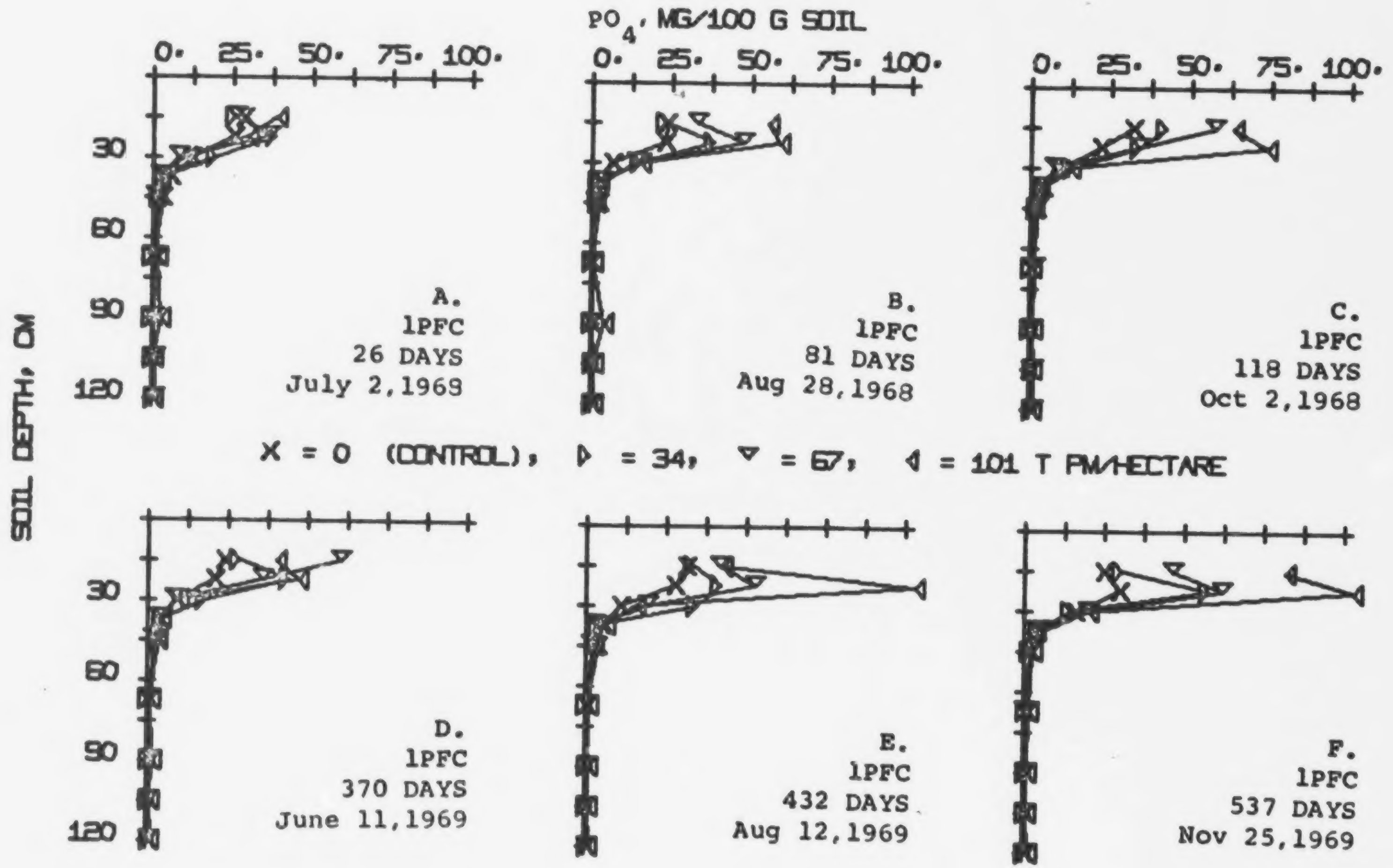


Figure 40. DISTRIBUTION OF BRAY-PHOSPHATE IN THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC (AUGUST 2, 1968), AND 1PFC* (JUNE 6, 1968).

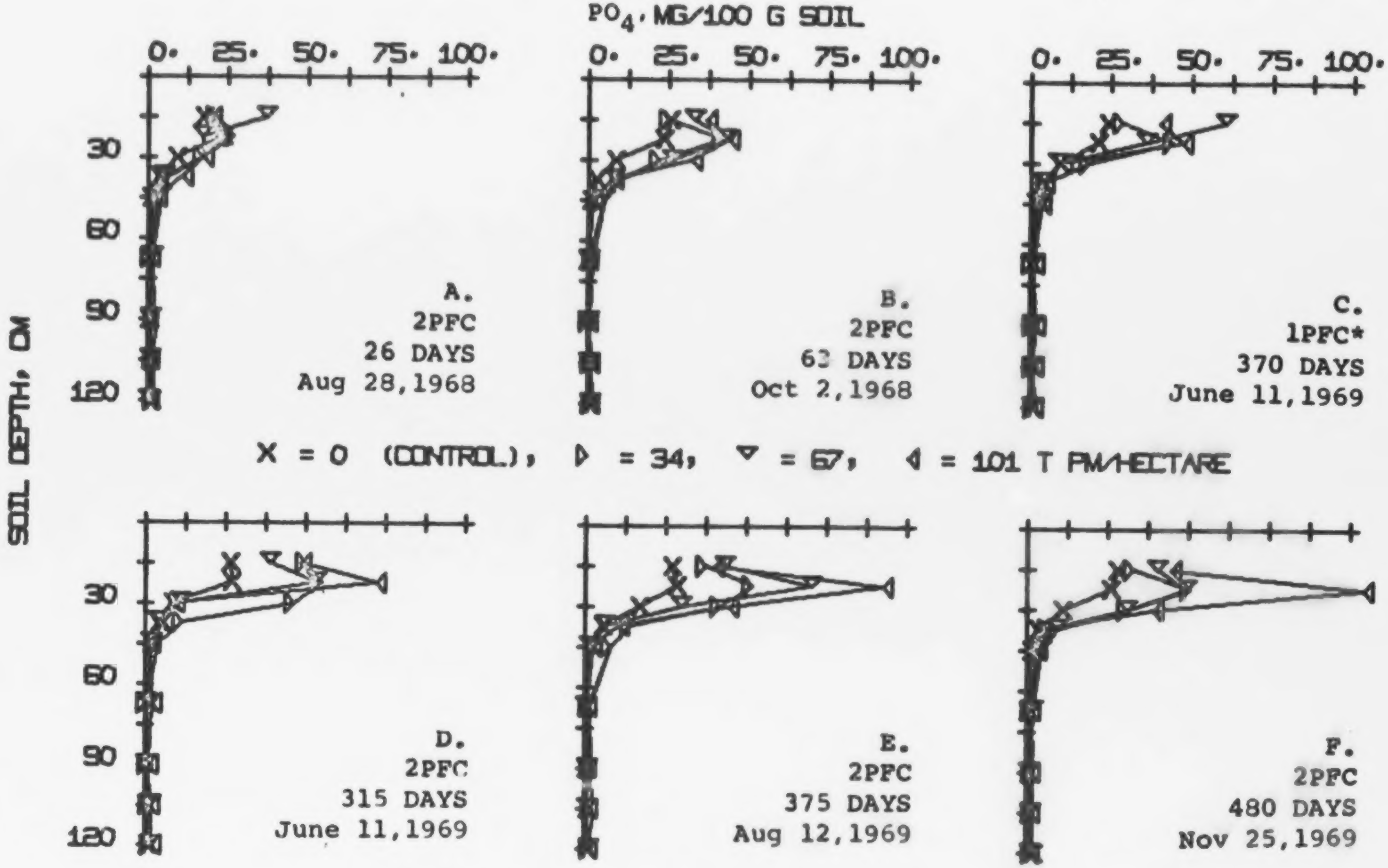


Figure 41. DISTRIBUTION OF BRAY-PHOSPHATE IN THE SOIL PROFILE SAMPLED ON AUGUST 12 AND NOVEMBER 25, 1969 FROM 1PFC, 2PFC AND 3PFC.

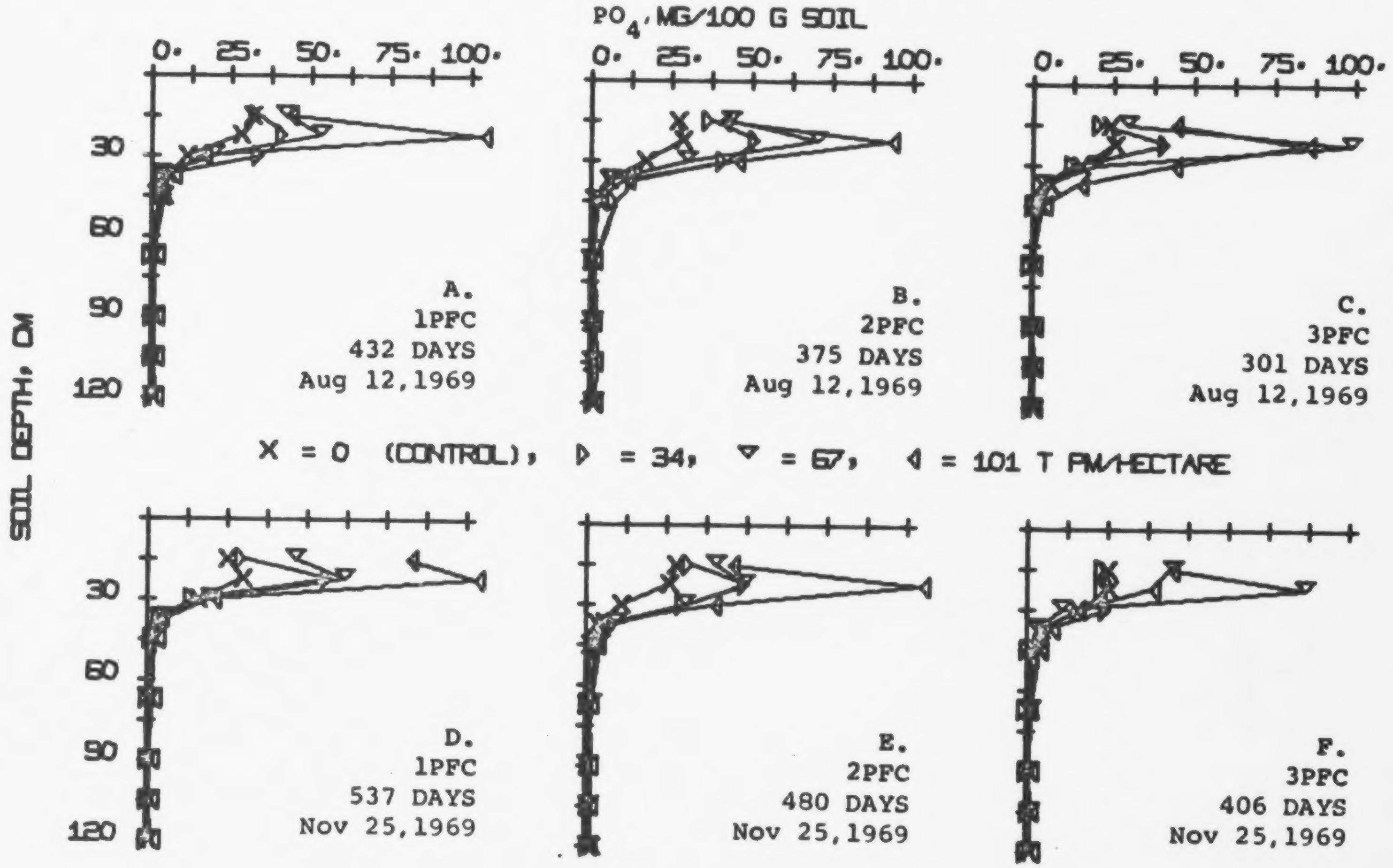


Figure 42. PHOSPHATE-P, BRAY EXTRACTION, INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) SAMPLED ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

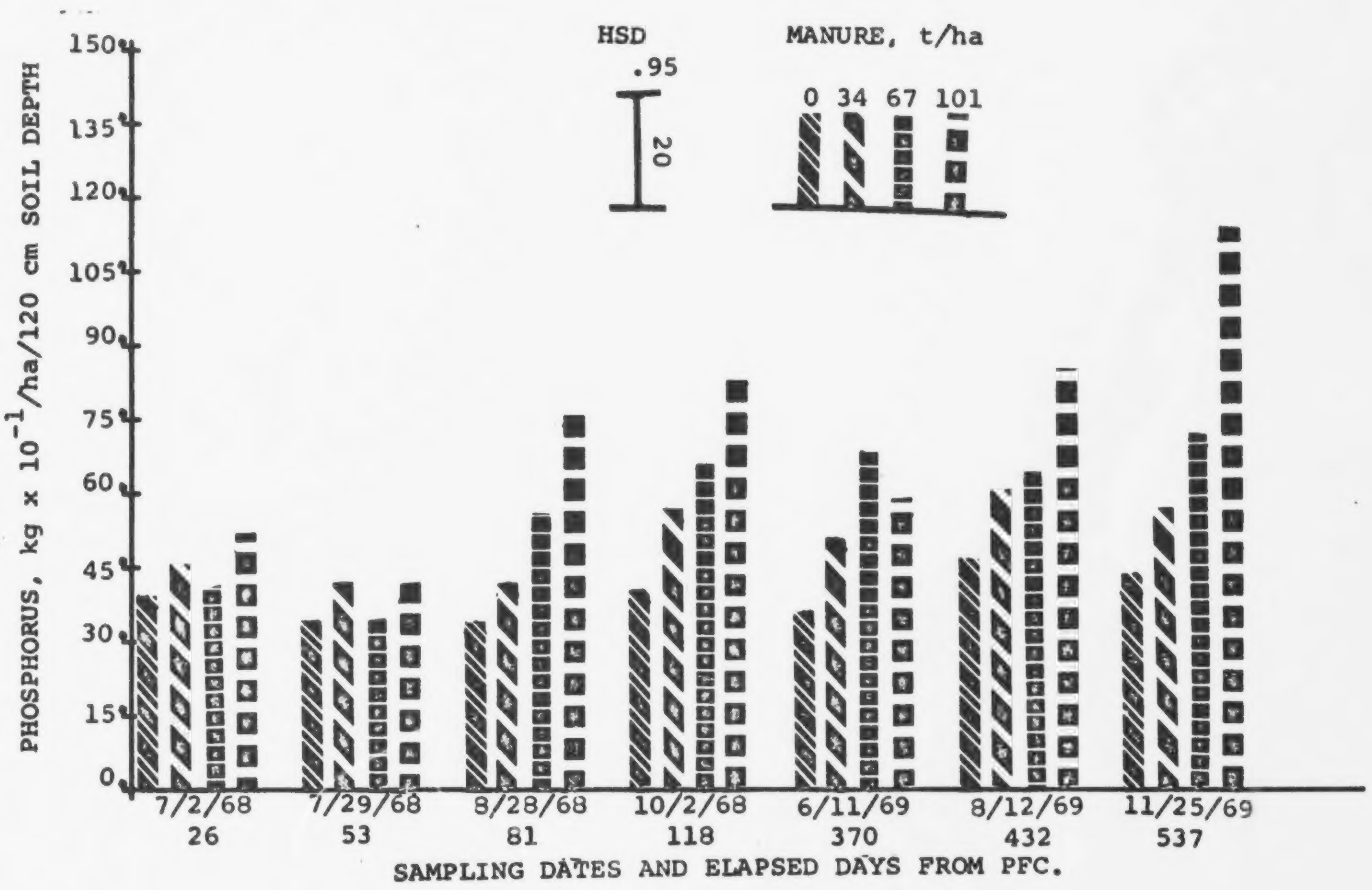
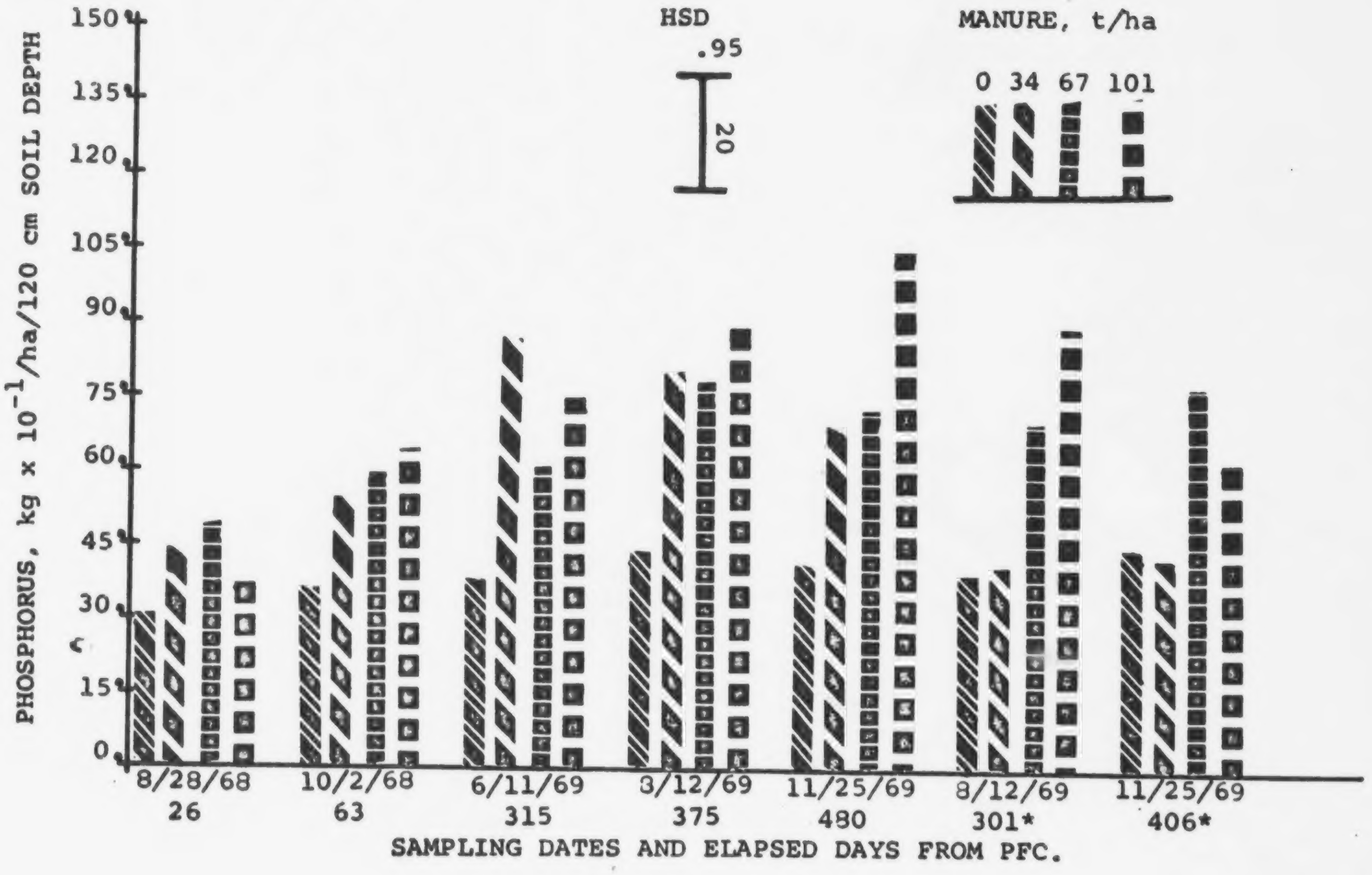


Figure 43. PHOSPHATE-P, BRAY EXTRACTION, INTEGRATED OVER THE SOIL PROFILE (0-120 cm DEPTH) FROM 2PFC (AUGUST 2, 1968) AND 3PFC* (OCTOBER 15, 1968).



PERCENTAGE RECOVERY OF THE VARIOUS ELEMENTS

The summed or integrated values of elements extracted from the soil profile provided a method for calculation of the percentage recovery of the elements studied. When the amount found in the control plot is deducted from the amount found in a manured plot, the remainder can be compared to the total amount of the element applied in the manure, and it can be expressed as a percentage of the total applied by the manure.

Percentage recovery indicates the retentiveness of the soil for the element and provides an idea of the change of the chemical composition of the drainage water from the soil. Low percentage recovery will indicate low retention and high pollution hazard, whereas high recovery indicates high retention or low mobility through the soil and low pollution hazard.

For the cations K, Ca, Mg, and Na, the summed values were obtained for the 22.5 to 120 cm soil profile depth. Since the manure was applied at a 17 cm depth, percentage recovery for these cations is related to: 1) mobility down from the PFC zone, 2)retention by the exchange sites of the clay in the soil, and 3) leaching below the 120 cm soil depth. Negative values are reported as zero.

The percentage recovery values for K, Ca, Mg, and Na are presented in Tables 12, 13, and 14. For K, for the 101 t/ha manure application the percentage recovery values are 41.7, 54.5, and 57.2 for the June 6, August 2, and October 15 application dates. The percentage recovery for Ca was low and this aspect has been discussed as "total calcium" (Tables 10 and 11). For Mg the percentage recovery values are 20.9, 71.1, and 65.46 for the three application dates of 101 t/ha manure. For Na the percentage recovery values are 30.1, 50.1, and 88.2.

For NH_4-N, and the anions NO_3-N, Cl, SO_4, and PO_4, the summed values were obtained for the 0 to 120 cm soil profile depth. The percentage recovery values for these elements therefore includes the manure application zone as a part of soil profile that was examined.

The percentage recovery values for NH_4-N, NO_3-N, Cl, SO_4, Bray-PO_4, and water-PO_4 are presented in Tables 15, 16, and 17. For NH_4-N the percentage recovery values are 2.1, 3.7, and 14.9 for the 101 t/ha manure applications on June 6, August 2, and October 15. The NO_3-N percentage recovery values are 1.9, 27.4, and 59.6. The total N (i.e. sum of NH_4-N and NO_3-N) percentage recovery values are 4.1, 31.1, and 74.5.

For the percentage recovery of the sum of NH_4-N and NO_3-N, it must not be assumed that the entire fraction of the total nitrogen not accountable has been lost from the soil profile. Part of the total applied manure nitrogen may still be present in the profile as organic nitrogen. On the other hand, that part of the manure nitrogen which is mineralized to ammonium and nitrate should be considered available for downward movement in the percolation water. With this in mind a considerable quantity of nitrogen was lost from the June 6 manure applications. However for the October 15 manure applications, a considerable amount of nitrogen (74.5%) was recovered as NH_4-N and NO_3-N 406 days and 51.79 inches of rainfall after the application.

For Cl the percentage recovery values are 15.8, 16.4, and 26.0 for the 101 t/ha manure treatments. For SO_4 the percentage recovery values are 0.0, 0.0, and 0.0. For Bray-PO_4 the recovery values are 28.7, 25.4, and 7.2. For water extractable-PO_4 the recovery values are 2.3, 1.6, and 0.5.

The percentage recovery values for both Bray-PO_4 and water extractable-PO_4 are misleading since these extraction methods extract only the "available" fraction of phosphorus from a soil, and the "fixed" PO_4 has not been evaluated.

Table 12. PERCENTAGE RECOVERY OF DIFFERENT CATIONS CALCULATED FROM THE SUMMED VALUES FOR THE SOIL PROFILE SAMPLED ON SEVEN DATES AFTER IPFC ON JUNE 6, 1968.

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES
PM:t/ha

PM	ELEMENT				
	K	CA	MG	NA	NH4
SAMPLED ON JULY 2, 1968 (26 DAYS AFTER IPFC)					
34	46.24	36.62	97.45	30.00	59.10
67	11.61	23.27	37.63	16.14	68.55
101	8.14	11.81	0.0	9.85	59.00
SAMPLED ON JULY 29, 1968 (53 DAYS AFTER IPFC)					
34	31.51	0.0	45.09	0.0	38.83
67	0.0	0.0	63.63	0.0	35.39
101	0.0	0.0	65.45	1.02	25.43
SAMPLED ON AUGUST 28, 1968 (81 DAYS AFTER IPFC)					
34	43.55	16.84	99.99	32.73	1.89
67	36.61	16.80	85.45	61.14	8.86
101	20.54	6.90	39.27	53.79	24.24
SAMPLED ON OCTOBER 2, 1968 (118 DAYS AFTER IPFC)					
34	0.0	0.0	36.00	0.0	1.44
67	6.63	0.0	12.00	0.0	14.36
101	1.22	5.40	19.03	8.94	9.70
SAMPLED ON JUNE 11, 1969 (370 DAYS AFTER IPFC)					
34	41.83	2.94	59.27	15.95	0.90
67	35.05	6.71	59.27	35.91	4.68
101	32.26	0.0	52.00	16.21	5.55
SAMPLED ON AUGUST 12, 1969 (432 DAYS AFTER IPFC)					
34	12.15	2.54	89.82	29.09	0.0
67	26.77	0.0	42.36	42.27	0.0
101	21.33	0.0	31.76	35.91	0.0
SAMPLED ON NOVEMBER 25, 1969 (537 DAYS AFTER IPFC)					
34	29.25	0.0	17.82	0.0	1.53
67	27.42	0.0	5.27	8.18	0.0
101	41.72	0.0	20.97	30.15	2.15

Table 13. PERCENTAGE RECOVERY OF DIFFERENT CATIONS CALCULATED FROM THE SUMMED VALUES FOR THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC ON AUG. 2, 1968.

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES
PM:t/ha

PM	ELEMENT				
	K	CA	MG	NA	NH4
SAMPLED ON AUGUST 28, 1968 (26 DAYS AFTER 2PFC)					
34	68.08	0.0	13.00	16.36	51.33
67	16.82	15.93	29.67	42.00	34.17
101	15.32	13.50	37.67	62.27	41.44
SAMPLED ON OCTOBER 2, 1968 (63 DAYS AFTER 2PFC)					
34	48.24	8.00	47.33	59.20	9.56
67	28.03	17.66	52.33	16.80	21.00
101	45.89	13.00	44.44	36.67	41.26
SAMPLED ON JUNE 11, 1969 (315 DAYS AFTER 2PFC)					
34	55.35	7.72	28.67	71.20	7.00
67	38.23	9.19	35.83	71.60	6.56
101	36.80	14.59	36.11	63.87	12.00
SAMPLED ON AUGUST 12, 1969 (375 DAYS AFTER 2PFC)					
34	58.69	0.0	42.33	14.68	0.54
67	30.30	15.49	45.84	40.47	4.32
101	45.05	11.46	54.78	46.63	7.03
SAMPLED ON NOVEMBER 25, 1969 (480 DAYS AFTER 2PFC)					
34	52.83	0.0	0.0	28.80	3.60
67	34.29	0.0	14.83	32.80	1.59
101	54.48	1.88	71.11	50.13	3.79

Table 14. PERCENTAGE RECOVERY OF DIFFERENT CATIONS CALCULATED FROM THE SUMMED VALUES FOR THE SOIL PROFILE SAMPLED ON TWO DATES AFTER 3PFC ON OCT. 15, 1968.

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES
PM:t/ha

PM	ELEMENT				
	K	CA	MG	NA	NH4
	SAMPLED ON AUGUST 12, 1969 (301 DAYS AFTER 3PFC)				
34	36.04	3.59	0.0	50.67	22.37
67	67.90	9.46	31.82	77.33	53.06
101	54.32	40.18	56.55	42.44	37.53
	SAMPLED ON NOVEMBER 25, 1969 (406 DAYS AFTER 3PFC)				
34	7.28	43.01	13.31	0.02	0.0
67	46.36	26.10	65.64	80.33	0.0
101	57.16	7.35	65.46	88.22	14.98

Table 15. PERCENTAGE RECOVERY OF DIFFERENT ELEMENTS ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES.
PM:t/ha

PM	ELEMENTS						
	NH4-N	NO3-N	NH4+NO3-N	CL	SO4	BRAY-P	WATER-P
	SAMPLED ON JULY 2, 1968(26 ELAPSED DAYS)						
34	59.10	13.47	72.57	47.71	0.00	6.72	-
67	68.55	1.86	70.41	47.08	0.00	0.81	-
101	59.00	1.29	60.29	66.58	15.38	4.52	-
	SAMPLED ON JULY 29, 1968 (53 ELAPSED DAYS)						
34	38.83	61.98	100.81	75.64	13.83	10.40	-
67	35.39	20.76	56.15	64.70	21.10	0.00	-
101	25.43	12.79	38.22	67.94	27.50	2.70	-
	SAMPLED ON AUGUST 28, 1968(81 ELAPSED DAYS)						
34	1.89	49.77	51.66	62.46	0.00	9.09	-
67	8.86	36.89	45.75	50.29	1.36	12.80	-
101	24.24	23.73	47.97	82.48	44.17	16.92	-
	SAMPLED ON OCTOBER 2, 1968(118 ELAPSED DAYS)						
34	1.44	71.65	73.09	74.48	0.00	19.57	2.58
67	14.36	50.19	64.55	77.70	8.99	15.47	3.55
101	9.70	31.99	41.69	67.27	4.04	17.71	2.58
	SAMPLED ON JUNE 11, 1969(370 ELAPSED DAYS)						
34	0.90	23.54	24.44	13.71	0.00	18.04	1.69
67	4.68	37.09	41.77	37.09	0.00	18.89	2.62
101	5.55	21.12	26.67	21.12	0.00	8.84	1.24
	SAMPLED ON AUGUST 12, 1969(432 ELAPSED DAYS)						
34	0.00	10.93	10.93	11.96	0.00	16.76	1.67
67	0.00	13.13	13.13	19.43	0.00	11.07	1.22
101	0.00	20.24	20.24	26.64	0.00	15.38	2.38
	SAMPLED ON NOVEMBER 15,1969(537 ELAPSED DAYS)						
34	1.53	12.62	14.15	0.00	23.84	16.61	0.79
67	0.00	2.52	2.52	1.60	23.06	18.14	1.69
101	2.15	1.95	4.10	15.84	0.00	28.73	2.33

Table 16. PERCENTAGE RECOVERY OF DIFFERENT ELEMENTS ON FIVE SAMPLING DATES AFTER 2PFC (AUGUST 2, 1968)

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES.
PM:t/ha

PM	ELEMENTS						
	NH4-N	NO3-N	NH4+NO3-N	CL	SO4	BRAY-P	WATER-P
SAMPLED ON AUGUST 28, 1968(26 ELAPSED DAYS)							
34	51.33	12.58	63.91	147.92	0.00	14.15	-
67	34.17	0.00	34.17	75.16	30.30	10.78	-
101	41.44	2.36	43.80	70.55	13.57	2.97	-
SAMPLED ON OCTOBER 2, 1968(63 ELAPSED DAYS)							
34	9.56	36.10	45.66	116.86	0.00	21.83	0.18
67	21.00	15.87	36.87	95.14	33.58	14.66	1.23
101	41.26	20.68	61.94	106.33	52.92	11.23	0.55
SAMPLED ON JUNE 11, 1969(315 ELAPSED DAYS)							
34	7.00	34.46	41.66	63.64	0.00	57.38	1.81
67	6.56	19.72	26.28	37.98	0.00	13.54	0.23
101	12.00	35.04	47.04	62.15	0.00	14.47	8.12
SAMPLED ON AUGUST 12, 1969(375 ELAPSED DAYS)							
34	0.54	11.89	12.43	5.77	0.00	44.58	1.61
67	4.32	21.96	26.28	29.60	0.00	19.98	0.86
101	7.03	25.25	32.28	25.89	0.00	18.22	1.12
SAMPLED ON NOVEMBER 15, 1969(480 ELAPSED DAYS)							
34	3.60	4.52	8.12	0.00	0.00	31.32	0.90
67	1.59	6.83	8.42	6.41	3.86	18.37	0.75
101	3.79	27.40	31.19	16.49	0.00	25.44	1.63

Table 17. PERCENTAGE RECOVERY OF DIFFERENT ELEMENTS ON TWO SAMPLING DATES AFTER 3PFC (OCTOBER 15, 1968).

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES.
PM:t/ha

PM	ELEMENTS						
	NH4-N	NO3-N	NH4+NO3-N	CL	SO4	BRAY-P	WATER-P
	SAMPLED ON AUGUST 12, 1969(301 ELAPSED DAYS)						
34	22.37	47.52	69.89	38.17	33.90	2.06	1.14
67	53.06	74.94	128.00	46.29	13.93	16.67	0.91
101	37.53	42.22	79.75	14.69	16.88	19.14	1.10
	SAMPLED ON NOVEMBER 15,1969(406 ELAPSED DAYS)						
34	0.00	12.39	12.39	3.07	12.78	0.03	0.07
67	0.00	69.72	69.72	22.06	0.00	19.08	1.70
101	14.98	59.61	74.59	26.06	0.00	7.26	0.54

DISCUSSION

The first application of poultry manure by Plow-Furrow-Cover was made on June 6, 1968 and the last soil samples for evaluation of the responses were taken on November 25, 1969. The rainfall was 68.91 inches in the 537 days.

In this period the cations K, Mg, and Na were observed to be mobile and downward movement from the manure application zone occurred. No large concentration of K was found in the soil water at 120 cm, however K was found at the 90 cm depth. Exchangeable K down to 90 to 105 cm depth was increased on the manure treatments. Mg was found at all depths in the soil water. Exchangeable Mg increased throughout the 120 cm depth. Na was found at all depths in the soil water. Exchangeable Na increased throughout the 120 cm depth and appreciable amounts were found at the 120 cm soil depth.

The cation Ca was found in large amounts in the soil water down to the 120 cm depth (Figure 10). Exchangeable Ca increased at the soil depths below the manure application zone and decreased below the control at soil depths of 60 to 120 cm. Much of the Ca applied in the manure was found in the manure application zone, and this Ca probably exists as an insoluble calcium salt of phosphate.

The cation NH_4 was found in the soil water down to 90 cm depth. Exchangeable NH_4 was found at all soil depths 26 days after the manure application and at the end of the experiment no NH_4 was found in the soil profile were manure had been applied 537 days earlier. No exchangeable NH_4 was found in the soil profile on November 25 where manure had been applied 480 days earlier on August 2. However, important amounts of exchangeable NH_4 were found at 45, 60, and 90 cm soil depths on November 25 where manure had been applied 406 days earlier on October 15. The reduction in soil temperature after the late autumn manure application will stop the nitrification process. The lowered soil temperature "preserves" the NH_4 for the next spring when the NH_4 will be transformed into new organic compounds by soil microorganisms. The immobilization of nitrogen serves to reduce the loss of nitrogen by leaching in the early spring and early summer, however the normal reactions of oxidation and nitrification will release the nitrogen - mineralization - at a later period in the season. The immobilization process did not prevent the appearance of NH_4 and NO_3; it only delayed the appearance of NH_4 and NO_3.

The anions Cl and SO_4 were found at all depths in the soil water. Water extractable Cl in the soil was at all soil depths within 81 days after the manure application. At the last sampling date only the largest manure application was found to influence the Cl; this Cl was found at 90, 105, and 120 cm soil depths. The soil had been nearly leached free of Cl. SO_4 was found in the soil water at all soil depths. The water extractable SO_4 from the soil was high in the manure application zone and in the 30 to 60 cm soil depth samples. The SO_4 was less on manure treatments than on the control at soil depths below 60 cm.

Only very small amounts of PO_4 were found in the soil water. The two extraction forms of PO_4 from the soil demonstrated a great retention of PO_4 by the soil. Neither water extractable-PO_4 nor Bray-PO_4 were found at soil depths of 45 cm or below.

NO_3-N was found in the soil water samples at all depths. The maximum concentration in the soil water was 590 ppm N at 120 cm depth. The NO_3-N concentration occurred 391 days and 29.59 inches of rainfall after the manure application had been made. Water extractable NO_3-N in the soil was low shortly after manure application, and later it increased to large values in the manure application zone. With time (and rainfall) this NO_3-N was distributed through the soil profile with large amounts found at the 120 cm depth, and at the end of the experiment NO_3-N had been leached almost completely from the soil profile where the manure application had been made on June 6. Where the manure had been applied in late autumn (October 15), large amounts of water extractable NO_3-N were present from 30 cm down to 120 cm. The immobilization of nitrogen by soil microorganisms was temporary and served only to delay the appearance of the nitrate in the soil. Moreover the amount of NO_3-N was almost the maximum found, and this occurred at soil depths greater than at any other sampling time.

This field experiment from the beginning did not have a cover crop except for a brief period of weed growth in 1968. The original plan called for a cover crop in the second year. The low nitrogen content in the soil water (from suction lysimeters) on October 1968 indicated that only a small amount of nitrogen had been moved downward into the 120 cm soil depth. An important objective of the experiment was to determine the time that nitrogen would appear at this depth. Consequently, no cover crop was seeded in 1969, and the treated sites were maintained free of plants in order to eliminate the interaction of root removal of or interception of soluble forms of nitrogen.

It is important to recognize the striking change in the water extractable NO_3-N distribution between the soil sampling of October 2, 1968 and the soil sampling of June 11, 1969 (Figure 19, graphs C and D, and Figure 20, graphs B and D). This indicates a large mobility of NO_3-N during the spring months when large amounts of water percolate through the soil and when tile drains are active.

A cover crop will certainly lower the amount of nitrogen in the soil water and will slow the downward movement of nitrogen in the soil percolate. This aspect must be studied. However, the recovery of nitrogen by an active cover crop may be as much as 66% when 30 t/ha of manure (or 1000 kg N/ha) have been applied into the soil. For larger manure applications the recovery will decrease to less than 20%. The actual data (Figure 23) show that 150, 1330, and 1700 kg of NO_3-N were water extractable from a hectare of soil to a depth of 120 cm for the 34, 67, and 101 t/ha manure applications. These amounts of NO_3-N existed in the soil on November 25, 406 days and 51.79 inches of rainfall after the late autumn manure application on October 15. Very few winter cover crops have the capability of removing 200 kg N/ha from the soil. The importance of the cover crop in the recovery of nitrogen from the soil and soil percolate must not be underestimated, however, it must not be overestimated as an effective method for the recovery of nitrogen when large amounts of nitrogen have been applied as poultry manure.

SUMMARY

Poultry manure has been disposed of in Freehold loamy sand soil, and its effect upon the soil water and soil have been investigated for eighteen months following the disposal applications by Plow-Furrow-Cover (PFC). The water free amounts of manure PFC were 0, 34, 67, and 101 metric tons/ha.

Soil water collected on five dates by suction lysimeters positioned at five depths down to 120 cm contained soluble K, Ca, Mg, Na, NH_4-N, NO_3+NO_2-N, Cl, SO_4, and PO_4. The amounts of soluble material integrated for the soil profile increased with increased manure applications. K, Mg, Na, Cl, SO_4, and PO_4 in the soil water peaked 83 days (15.52 inches of rain) after PFC. NO_3+NO_2 peaked 391 days (53.94 inches of rain) after PFC. NH_4 decreased from a high to a low amount in 391 days. Ca was high at all sampling dates. PO_4 increased over the 428 day period.

Soil samples collected as 15 segments to a depth of 120 cm were taken on 7 dates after PFC. Exchangeable K, Mg, Na, and NH_4 integrated for the soil profile increased with increased manure applications. In the 537 days K increased, Mg and Na peaked and then decreased, NH_4 decreased to low values, and Ca increased in 26 days than decreased progressively to amounts less than the unmanured soil profiles. Extractable anions from the soil samples increased with increased manure applications. NO_3+NO_2-N increased for 119 days after PFC. Cl peaked in 82 days and decreased at the next two sampling dates (371 days from PFC). PO_4 (Bray #1) in the soil profile increased with increased manure applications and with subsequent soil sampling dates.

The percentage of the total nitrogen added as manure and recovered as exchangeable NH_4 and water extractable NO_3+NO_2 in the soil profile decreased from 70 to 50 to 30% in 1, 2½, and 12 months after PFC. These percentages of nitrogen recovery indicate nitrogen losses from the soil.

PFC applications in late fall, October 15, accounted for large amounts of exchangeable NH_4 in the soil profile ten months later. Split applications of manure, one half in May and one half in August, contained less exchangeable NH_4 than the full application in August.

Each of the elements studied, except for PO_4, were found to have moved appreciably from the 17 cm depth PFC placement into lower depths of the soil. The movement was demonstrated in soil water samples (from suction lysimeters) obtained at 30, 45, 60, 90, and 120 cm soil depths. Elements extracted from the soil, except for PO_4, were demonstrated to have moved to soil depths from 60 to 120 cm.

There should be real concern for nutrient contamination of the water percolating thru a soil into which disposal amounts of poultry manure have been applied. Late autumn application of manure PFC increased the amounts of exchangeable NH_4-N and water extractable NO_3-N in the soil at depths of 60 and 90 cm when sampled 406 days after the manure application.

ACKNOWLEDGEMENTS

The field experiment and analytical phase of the poultry manure disposal research grant was conducted with the assistance of many people. Dr. Jose Badillo-Feliciano and Dr. George Nzewi, as graduate students, were responsible for cation and anion extractions and analyses of soil samples. Mr. Harold Henderson (who completed the M.S. degree) and Mr. Phillip Warman, as graduate students, were associated with the research prior to being called to military service. Mr. Julius Szamel, as chemist, developed the AutoAnalyzer system for chemical analysis, and Mr. Nicklas Rogers was responsible for a significant portion of the routine chemical analyses. Mr. Kenneth Burbank and Mr. Herbert Bedwinik, as computer programmers, provided invaluable assistance. Professor Charles H. Reed and Mr. Jack Martin made the PFC applications on the many plots and dates. With their skill in PFC application the field work became possible. Mr. Edward Vicinski and his staff at the Soils and Crops Research Center provided the required small and large machinery and assistance so necessary for field experimentation. Mrs. Emma Rivera efficiently and graciously has typed the report. To each of these and to many unnamed people, I express my sincere thanks for their industry, sincerity, devotion, and wholesome attitude in accomplishing the research objectives even on those days requiring PFC.

APPENDIX SECTION

The appendix tables which follow are included to make available the great volume of data which have been tabulated. Many of the appendix tables were referred to in the body of this report and perhaps more have not.

The variability of the soil was below the surface as is shown by the percentages of clay and silt at different depths (Appendix 16).

Appendix 1. Potassium Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

		Sampling Date and Days from PFC on June 6, 1968				
Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Potassium, kg/11 cm soil depth/ha				
None	30	2	3	3	2	2
	45	-	20	-	1	2
	60	1	20	-	1	1
	90	3	-	-	1	1
	120	7	-	-	-	-
34	30	24	4	85	17	9
	45	8	4	17	5	4
	60	8	44	13	6	4
	90	4	4	2	2	2
	120	1	1	-	1	-
67	30	43	-	98	25	18
	45	9	17	9	13	11
	60	1	40	2	5	7
	90	4	6	4	14	6
	120	1	17	-	2	2
101	30	45	117	34	47	25
	45	23	-	18	102	55
	60	-	87	6	5	7
	90	13	50	3	3	2
	120	1	9	-	3	1

1/ Water-free poultry manure.

Appendix 2. Calcium Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Calcium, kg/11 cm soil depth/ha				
None	30	26	13	8	8	7
	45	12	24	17	13	12
	60	10	6	15	7	8
	90	14	13	8	6	7
	120	4	10	6	6	6
34	30	80	-	96	18	10
	45	23	120	124	13	9
	60	40	105	89	12	11
	90	25	14	22	17	25
	120	11	10	9	47	13
67	30	116	300	212	20	10
	45	55	90	131	26	14
	60	23	28	36	52	17
	90	21	10	15	58	42
	120	15	10	22	80	58
101	30	68	178	234	32	14
	45	58	194	147	139	112
	60	21	64	85	111	61
	90	42	40	31	116	83
	120	11	13	7	90	106

1/ Water-free poultry manure.

Appendix 3. Magnesium Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Magnesium, kg/11 cm soil depth/ha				
None	30	10	1	4	3	3
	45	3	14	2	–	6
	60	3	1	3	2	2
	90	2	1	1	1	1
	120	2	2	2	1	1
34	30	22	53	65	10	6
	45	11	36	55	4	2
	60	10	19	41	4	3
	90	4	4	4	4	4
	120	3	3	2	19	3
67	30	32	39	105	8	4
	45	24	42	55	12	6
	60	4	13	11	14	6
	90	6	3	6	30	11
	120	6	1	4	23	13
101	30	25	64	89	14	4
	45	26	63	65	54	34
	60	9	15	23	32	18
	90	10	12	7	26	17
	120	12	4	3	28	19

1/ Water-free poultry manure.

Appendix 4. Sodium Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Sodium, kg/11 cm soil depth/ha				
None	30	3	6	3	1	1
	45	-	9	4	1	1
	60	-	14	3	1	1
	90	2	3	4	1	1
	120	-	1	2	1	1
34	30	12	21	30	3	2
	45	11	100	20	11	2
	60	13	28	9	3	2
	90	7	6	7	2	4
	120	1	7	2	7	3
67	30	30	2	55	6	3
	45	11	20	18	9	3
	60	3	42	6	13	4
	90	4	28	4	10	11
	120	2	23	4	14	12
101	30	43	116	31	9	4
	45	20	-	31	34	19
	60	-	168	17	21	15
	90	26	56	10	19	20
	120	3	6	1	10	18

1/ Water-free poultry manure.

Appendix 5. Ammonium-Nitrogen Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

		Sampling Date and Days from PFC on June 6, 1968				
Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Ammonium-N, kg/11 cm soil depth/ha				
None	30	1	-	-	-	-
	45	2	1	-	-	-
	60	2	1	-	-	-
	90	1	-	-	-	-
	120	6	-	-	-	-
34	30	6	2	-	-	-
	45	6	4	4	-	-
	60	2	1	2	-	-
	90	5	-	-	-	-
	120	1	-	-	-	-
67	30	56	47	24	-	-
	45	2	1	-	-	-
	60	2	1	4	-	-
	90	3	-	1	-	-
	120	1	-	-	-	-
101	30	97	63	30	11	-
	45	26	4	3	7	1
	60	4	17	1	-	-
	90	19	13	-	1	-
	120	1	-	-	-	-

1/ Water-free poultry manure.

Appendix 6. Nitrate + Nitrite-Nitrogen Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		$NO_3 + NO_2$-N, kg/11 cm soil depth/ha				
None	30	15	7	6	7	6
	45	-	17	6	3	2
	60	6	4	4	2	3
	90	-	4	2	-	1
	120	-	2	2	2	1
34	30	50	100	151	25	10
	45	59	89	113	9	7
	60	14	55	112	9	3
	90	4	11	11	22	44
	120	1	2	2	58	11
67	30	-	-	133	30	10
	45	89	84	134	34	11
	60	8	26	28	66	7
	90	-	6	13	65	41
	120	-	2	8	133	50
101	30	55	310	311	50	13
	45	36	136	77	160	124
	60	-	32	39	158	59
	90	-	15	13	146	78
	129	-	3	2	88	89

1/ Water-free poultry manure.

Appendix 7. Chloride Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Chloride, kg/11 cm soil depth/ha				
None	30	2	1	4	2	1
	45	13	2	-	2	2
	60	6	2	1	2	1
	90	9	2	-	1	1
	120	15	1	1	1	1
34	30	84	58	47	2	1
	45	36	45	37	4	1
	60	42	57	34	2	1
	90	20	13	8	4	4
	120	7	4	3	11	3
67	30	-	143	114	2	1
	45	47	51	53	7	2
	60	43	32	21	20	1
	90	53	11	17	24	11
	120	8	8	11	29	17
101	30	108	246	160	3	1
	45	122	136	124	14	8
	60	23	45	57	36	12
	90	37	56	29	59	21
	120	-	18	1	76	39

1/ Water-free poultry manure.

Appendix 8. Sulfate Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Sampling Date and Days from PFC on June 6, 1968				
		Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Sulfate, kg/11 cm soil depth/ha				
None	30	-	9	11	7	3
	45	-	40	13	17	12
	60	10	22	18	11	10
	90	19	21	20	10	17
	120	6	23	17	14	12
34	30	-	108	56	17	14
	45	26	63	15	10	12
	60	7	21	7	11	12
	90	8	8	14	3	9
	120	21	21	19	-	12
67	30	15	97	61	14	14
	45	11	141	17	20	12
	60	13	18	17	11	29
	90	8	10	13	11	10
	120	18	11	15	-	10
101	30	75	37	50	14	15
	45	8	444	19	20	35
	60	12	47	12	22	20
	90	61	44	20	15	11
	120	13	22	23	-	15

1/ Water-free poultry manure.

Appendix 9. Phosphate Dissolved in the Soil Water at Five Depths After PFC Application of Poultry Manure.

(averages of 2 or 3 replicates)

		Sampling Date and Days from PFC on June 6, 1968				
Poultry Manure Treatment t/ha 1/	Sampling Depth, cm	Aug. 1, 1968 57 days	Aug. 27, 1968 83 days	Oct. 14, 1968 131 days	July 1, 1969 391 days	Aug. 7, 1969 428 days
		Phosphate, kg/11 cm soil depth/ha				
None	30	-	-	-	-	0.1
	45	-	-	1.1	-	-
	60	-	-	0.2	0.3	-
	90	0.4	-	-	-	-
	120	-	-	-	-	-
34	30	-	5.4	2.1	-	2.4
	45	-	0.9	-	0.5	0.2
	60	-	-	1.1	0.4	0.2
	90	-	-	0.2	-	-
	120	-	0.1	0.1	-	-
67	30	-	-	0.4	0.2	0.2
	45	-	-	-	0.7	1.1
	60	-	-	-	-	0.5
	90	-	-	0.1	-	0.1
	120	-	-	1.9	-	-
101	30	-	2.0	-	0.6	1.8
	45	-	1.2	0.2	0.9	-
	60	-	1.4	1.1	4.6	1.9
	90	-	0.6	0.3	0.2	0.5
	120	-	0.2	-	0.8	-

1/ Water-free poultry manure.

Appendix 10 SUMMED CEC AND EXCHANGEABLE CATIONS IN THE 22 - 120 CM SOIL DEPTH SAMPLED ON SEVEN DATES AFTER 1PFC ON JUNE 6, 1968 (0 - 120 CM DEPTH FOR NH4-N).

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES

PM= t/ha; CEC= me/cm^2/soil depth; Elements= kg/ha/soil depth

PM		ELEMENT.				
	CEC	K	CA	MG	NA	NH4-N
	SAMPLED ON JULY 2, 1968 (26 DAYS AFTER 1PFC)					
0	15.6	1142.8	7211.8	1679.2	469.6	474.7
34	16.9	1572.1	8207.8	1947.0	535.3	1130.3
67	17.9	1358.7	8477.3	1886.9	540.2	1982.5
101	18.5	1369.5	8175.5	1671.7	534.9	2421.3
	SAMPLED ON JULY 29, 1968 (53 DAYS AFTER 1PFC)					
0	21.7	1884.9	8594.9	1649.1	664.9	159.4
34	21.1	2177.3	7345.8	1773.5	619.8	589.7
67	19.6	1625.6	7744.0	1684.7	568.0	941.6
101	19.5	1509.7	9944.5	1703.5	732.2	998.1
	SAMPLED ON AUGUST 28, 1968 (81 DAYS AFTER 1PFC)					
0	21.6	1260.0	7728.3	1557.2	562.8	460.1
34	22.6	1664.5	8186.3	1839.9	634.9	480.7
67	22.8	1940.3	8642.3	2027.9	631.3	655.4
101	20.1	1832.0	8291.1	1881.6	917.4	1259.7
	SAMPLED ON OCTOBER 2, 1968 (118 DAYS AFTER 1PFC)					
0	21.9	1652.4	7600.9	1556.8	606.3	200.8
34	21.7	1470.8	7230.8	1655.8	489.5	216.1
67	20.0	1663.2	7176.9	1622.8	590.2	516.1
101	20.3	1686.8	8041.5	1713.8	664.9	519.8

(CONTINUED)

Appendix 10 (CONTINUED). SUMMED CEC AND EXCHANGEABLE CATIONS IN THE 22 - 120 CM SOIL DEPTH SAMPLED ON SEVEN DATES AFTER 1PFC ON JUNE 6, 1968 (0 - 120 CM DEPTH FOR NH4-N).

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES

PM= t/ha; CEC= me/cm^2/soil depth; Elements= kg/ha/soil depth

PM			ELEMENT,			
	CEC	K	CA	MG	NA	NH4-N
	SAMPLED ON JUNE 11, 1969 (370 DAYS AFTER 1PFC)					
0	18.1	1389.9	7219.7	1526.2	524.0	221.6
34	17.9	1778.5	7299.0	1689.3	875.3	233.2
67	17.7	2041.6	7584.2	1852.5	683.0	325.2
101	17.3	2289.4	7028.2	1825.4	631.1	405.2
	SAMPLED ON AUGUST 12, 1969 (432 DAYS AFTER 1PFC)					
0	19.1	1339.0	6008.7	1713.8	409.8	273.0
34	19.6	1451.7	6078.0	1960.1	473.4	239.0
67	18.9	1836.5	5547.1	1946.4	595.1	195.5
101	19.3	1933.9	5391.0	1975.9	646.9	223.2
	SAMPLED ON NOVEMBER 25, 1969 (537 DAYS AFTER 1PFC)					
0	18.9	1293.1	5844.1	1378.1	254.7	198.5
34	18.2	1565.8	5651.3	1427.1	252.4	215.9
67	18.9	1804.0	5670.9	1407.4	290.0	199.4
101	19.9	2457.5	5376.9	1571.0	453.8	259.3
		HSD BETWEEN 4 TREATMENT MEANS				
.95	2.4	630.9	1306.9	392.4	309.2	369.3
.99	2.9	775.9	1607.5	482.6	380.3	454.2

Appendix 11 SUMMED CEC AND EXCHANGEABLE CATIONS IN THE 22 - 120 CM SOIL DEPTH SAMPLED ON FIVE DATES AFTER 2PFC ON AUG. 2, 1968 (0 - 120 CM DEPTH FOR NH4-N).

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES

PM= t/ha; CEC= me/cm^2 /soil depth; Elements= kg/ha/soil depth

PM			ELEMENT.			
	CEC	K	CA	MG	NA	NH4-N
	SAMPLED ON AUGUST 28, 1968 (26 DAYS AFTER 2PFC)					
0	20.5	874.0	7028.9	1439.8	444.8	455.0
34	20.1	1547.9	6862.0	1478.7	853.5	917.2
67	20.6	1206.5	7452.6	1617.3	654.8	1070.2
101	21.1	1328.8	8184.0	1778.0	911.4	1573.9
	SAMPLED ON OCTOBER 2, 1968 (63 DAYS AFTER 2PFC)					
0	21.1	1241.5	6229.5	1359.9	436.5	326.8
34	19.6	1719.9	6517.6	1501.9	584.5	413.4
67	19.7	1796.3	7236.6	1673.3	520.3	705.2
101	18.9	2604.7	7381.7	1759.0	711.9	1441.3
	SAMPLED ON JUNE 11, 1969 (315 DAYS AFTER 2PFC)					
0	17.8	1307.1	5761.8	1391.8	373.8	352.6
34	17.5	1855.6	5541.6	1477.2	551.5	416.4
67	18.3	2064.5	6285.4	1606.5	731.4	471.0
101	18.2	2400.2	6923.7	1716.9	852.0	676.8
	SAMPLED ON AUGUST 12, 1969 (375 DAYS AFTER 2PFC)					
0	20.7	1542.2	7107.0	1681.0	252.5	224.1
34	19.9	2123.8	6438.6	1807.3	362.5	229.8
67	21.4	2142.2	7989.9	1955.1	556.9	318.5
101	19.8	2880.5	8086.2	2173.1	602.2	455.7
	SAMPLED ON NOVEMBER 25, 1969 (480 DAYS AFTER 2PFC)					
0	20.4	1065.1	5201.8	2442.0	191.6	203.5
34	17.7	1588.7	4561.6	2027.3	263.7	242.8
67	18.9	1744.1	5041.8	2530.1	355.4	236.4
101	18.9	2683.0	5362.6	3081.2	567.3	328.4
	HSD BETWEEN 4 TREATMENT MEANS					
.95	2.4	630.9	1306.9	392.4	309.2	369.3
.99	2.9	775.9	1607.5	482.6	380.3	454.2

Appendix 12 SUMMED CEC AND EXCHANGEABLE CATIONS IN THE 22 - 120 CM SOIL DEPTH SAMPLED ON TWO DATES AFTER 3PFC ON OCT. 15. 1968 AND SPFC ON MAY 5 AND AUG. 2. 1968 (0 - 120 CM DEPTH FOR NH4-N).

AVERAGE OVER TWO CORES FROM EACH OF THREE REPLICATES

PM= t/ha; CEC= me/cm^2/soil depth; Elements= kg/ha/soil depth

PM			ELEMENT,			
	CEC	K	CA	MG	NA	NH4-N
	SAMPLED ON AUGUST 12. 1969 (301 DAYS AFTER 3PFC)					
0	14.9	1217.9	6283.8	1695.2	182.2	203.1
34	14.6	1509.7	6382.4	1548.3	258.5	411.6
67	14.5	2317.4	6815.9	1870.3	414.7	1188.4
101	14.5	2537.8	6950.8	2006.3	373.4	1246.9
	SAMPLED ON NOVEMBER 25. 1969 (406 DAYS AFTER 3PFC)					
0	19.7	1207.8	6434.0	1261.1	319.3	248.3
34	19.3	1266.4	7621.8	1627.6	323.1	204.4
67	20.9	1958.1	7875.9	1622.8	560.5	423.0
101	20.6	2596.4	7050.1	1801.1	716.8	666.3
	SAMPLED ON AUGUST 12. 1969 (464 DAYS AFTER SPFC)					
0	17.8	1455.5	7373.5	1828.0	523.3	293.4
34	18.0	1686.1	5973.8	1464.9	579.3	303.9
67	17.9	1505.2	6411.8	1512.3	538.7	266.8
101	18.0	1500.8	6326.2	1473.6	540.2	301.1
	SAMPLED ON NOVEMBER 25. 1969 (569 DAYS AFTER SPFC)					
0	18.2	1640.9	5011.7	2368.0	265.2	213.6
34	17.7	1872.8	4315.9	2215.8	229.2	219.1
67	17.5	2221.9	4506.7	2468.9	374.9	210.4
101	17.7	2309.8	4907.2	2453.0	363.6	221.4
	HSD BETWEEN 4 TREATMENT MEANS					
.95	2.4	630.9	1306.9	392.4	309.2	369.3
.99	2.9	775.9	1607.5	482.6	380.3	454.2

Appendix 13 ANIONS INTEGRATED OVER THE SOIL PROFILE SAMPLED ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

AVERAGE OF TWO CORES FROM EACH OF THREE REPLICATES.
PM=t/ha ELEMENT= kg/ha

PM			ELEMENT		
	NO3-N	CL	SO4	BRAY-P	WATER-P
SAMPLED ON JULY 2, 1968(26 ELAPSED DAYS)					
0	102.57	201.00	2064.23	391.33	-
34	250.68	415.68	1871.35	447.07	-
67	143.58	624.75	1887.98	404.69	-
101	145.23	1099.85	2271.87	503.97	-
SAMPLED ON JULY 29,1968(53 ELAPSED DAYS)					
0	75.27	85.32	1488.67	334.59	-
34	757.05	425.72	1550.90	420.89	-
67	531.95	667.65	1678.55	330.66	-
101	497.40	1002.52	1861.12	401.79	-
SAMPLED ON AUGUST 28, 1968(81 ELAPSED DAYS)					
0	125.10	86.90	1527.67	336.89	-
34	672.68	367.98	1336.35	412.30	-
67	936.70	539.48	1539.90	549.39	-
101	908.31	1200.35	2123.92	758.10	-
SAMPLED ON OCTOBER 2, 1968(118 ELAPSED DAYS)					
0	168.27	71.13	1510.72	400.21	9.16
34	956.42	406.28	1243.27	562.66	30.58
67	1272.40	770.45	1551.15	657.01	68.05
101	1224.02	979.22	1565.20	841.20	73.33

(CONTINUED)

Appendix 13 (CONTINUED). ANIONS INTEGRATED OVER THE SOIL PROFILE SAMPLED ON SEVEN DATES AFTER 1PFC (JUNE 6, 1968).

AVERAGE OF TWO CORES FROM EACH OF THREE REPLICATES.
PM=t/ha ELEMENT=kg/ha

PM	ELEMENT				
	NO3-N	CL	SO4	BRAY-P	WATER-P
SAMPLED ON JUNE 11, 1969(370 ELAPSED DAYS)					
0	125.43	155.73	1309.83	358.50	9.52
34	384.33	217.42	1096.92	508.24	23.57
67	941.38	458.35	988.03	672.13	53.06
101	822.43	505.45	1283.88	578.66	40.42
SAMPLED ON AUGUST 12, 1969(432 ELAPSED DAYS)					
0	42.77	94.68	1364.63	455.65	12.06
34	163.03	148.52	1330.83	594.74	25.59
67	331.52	269.58	1286.08	639.38	26.37
101	710.53	454.38	1294.80	838.67	71.32
SAMPLED ON NOVEMBER 15, 1969(537 ELAPSED DAYS)					
0	97.87	47.17	1247.53	417.51	13.77
34	236.67	46.00	1354.83	555.36	20.33
67	153.23	61.57	1455.10	718.68	41.86
101	162.13	260.97	1245.10	1132.76	71.74
HSD BETWEEN 4 TREATMENT MEANS					
.95	263.85	182.78	233.12	196.45	21.37
.99	350.72	242.97	309.89	260.92	28.38

Appendix 14 ANIONS INTEGRATED OVER THE SOIL PROFILE SAMPLED ON FIVE DATES AFTER 2PFC (AUGUST 2, 1968).

AVERAGE OF TWO CORES FROM EACH OF THREE REPLICATES.
PM= t/ha   ELEMENT=kg/ha

PM	ELEMENT				
	NO3-N	CL	SO4	BRAY-P	WATER-P
SAMPLED ON AUGUST 28, 1968(26 ELAPSED DAYS)					
0	150.70	239.35	1399.63	304.65	-
34	263.95	727.50	1306.88	422.11	-
67	147.50	735.37	1672.32	483.64	-
101	214.23	937.82	1582.88	378.54	-
SAMPLED ON OCTOBER 2, 1968(63 ELAPSED DAYS)					
0	118.87	37.63	1393.03	354.39	7.22
34	443.75	423.26	1223.65	535.60	8.75
67	404.60	665.52	1695.22	595.68	27.44
101	677.18	1090.33	2107.43	634.04	21.01
SAMPLED ON JUNE 11, 1969(315 ELAPSED DAYS)					
0	42.07	136.02	1430.22	383.18	22.60
34	352.23	346.02	1162.60	859.47	37.64
67	379.03	386.67	1235.33	607.86	26.37
101	988.05	751.30	1184.38	578.66	80.00
SAMPLED ON AUGUST 12, 1969(375 ELAPSED DAYS)					
0	40.52	59.25	1486.53	438.01	7.40
34	147.52	78.30	1384.50	808.01	20.79
67	435.85	254.60	1320.05	769.64	21.74
101	722.32	312.60	1282.75	891.66	35.16
SAMPLED ON NOVEMBER 15, 1969(480 ELAPSED DAYS)					
0	34.87	62.63	1197.43	412.38	6.98
34	75.53	51.47	1057.27	672.39	14.48
67	157.73	99.23	1232.17	717.33	19.43
101	774.57	225.80	1121.03	1045.70	47.62
HSD BETWEEN 4 TREATMENT MEANS					
.95	263.85	182.78	233.12	196.45	21.37
.99	350.72	242.97	309.89	260.92	28.38

Appendix 15 ANIONS INTEGRATED OVER THE SOIL PROFILE SAMPLED ON TWO AFTER 3PFC (OCTOBER 15,1968) AND SPFC (MAY 5 AND AUGUST 2,1968).

AVERAGE OF TWO CORES FROM EACH OF THREE REPLICATES.
PM= t/ha ELEMENT= kg/ha

PM			ELEMENT		
	NO3-N	CL	SO4	BRAY-P	WATER-P
SAMPLED ON AUGUST 12, 1969(301 DAYS AFTER 3PFC)					
0	47.70	56.90	1203.17	386.61	10.30
34	489.60	205.75	1012.62	404.53	20.20
67	1441.53	418.00	1022.33	696.67	26.10
101	1225.63	316.83	1099.12	886.15	39.00
SAMPLED ON NOVEMBER 25, 1969(406 DAYS AFTER 3PFC)					
0	34.00	52.93	1192.80	446.04	7.98
34	149.23	64.90	1231.13	429.34	8.55
67	1330.73	224.97	739.17	778.22	37.56
101	1697.17	357.53	873.93	635.51	22.13
SAMPLED ON AUGUST 12, 1969(464 DAYS AFTER SPFC)					
0	25.48	64.05	1257.68	311.59	10.81
34	126.10	92.32	1359.37	319.19	13.91
67	308.43	194.18	1341.28	975.77	28.87
101	334.40	132.65	1409.57	595.58	32.22
SAMPLED ON NOVEMBER 15,1969(569 DAYS AFTER SPFC)					
0	37.67	54.77	1079.20	379.78	9.33
34	81.50	67.57	1303.27	612.80	18.46
67	278.80	102.33	1200.03	1027.07	36.03
101	482.57	103.90	1189.33	1009.50	35.69
HSD BETWEEN 4 TREATMENT MEANS					
.95	263.85	182.78	233.12	196.45	21.37
.99	350.72	242.97	309.89	260.92	28.38

Appendix 16 Percentages of Clay And Silt In Soil Of The PFC Sites.

averages of two soil cores

Experimental Sites for PFC on:	Soil Depth, cm	Replicate					
		1		2		3	
		%Clay	%Silt	%Clay	%Silt	%Clay	%Silt
June 6, 1968	30	9.0	11.2	21.7	25.9	10.2	13.5
	45	15.0	14.2	34.9	26.9	13.3	11.9
	60	22.8	9.3	30.1	19.5	19.3	7.5
	75	13.6	6.0	21.8	5.2	14.7	6.7
	90	13.6	6.0	21.8	5.2	14.7	6.7
	105	12.1	6.0	14.4	5.8	9.2	3.6
	120	12.6	4.5	12.3	2.7	10.3	4.9
August 2, 1968	30	11.4	9.5	14.4	23.6	14.6	18.8
	45	16.4	8.7	25.4	25.7	24.2	17.7
	60	15.7	6.8	22.6	25.0	28.5	13.1
	75	13.3	5.2	19.8	16.0	21.4	5.4
	90	13.3	5.2	19.8	16.0	21.4	5.4
	105	8.7	6.8	14.7	10.1	21.5	3.6
	120	10.8	4.1	12.8	8.0	17.5	4.3
October 15, 1968	30	26.3	19.8	13.9	23.3	15.0	27.9
	45	29.8	27.3	23.9	28.3	24.0	19.1
	60	29.8	26.2	31.0	24.6	20.0	12.3
	75	26.6	23.5	25.9	19.0	14.0	6.2
	90	19.6	19.6	21.8	14.6	9.9	4.2
	105	10.2	10.0	12.8	5.6	7.8	3.2
	120	6.7	7.5	8.9	3.5	11.8	3.2
Split Application 1/	30	8.5	13.3	14.4	19.1	12.3	22.1
	45	8.6	8.6	24.2	16.3	21.6	23.0
	60	4.8	6.9	20.4	10.9	20.2	17.7
	75	7.7	9.0	12.4	5.8	12.2	11.4
	90	16.9	10.9	8.3	5.4	6.0	6.2
	105	17.3	4.0	9.2	4.2	5.2	2.8
	120	13.8	4.7	10.2	4.0	4.6	3.3

1/ Split Application: May 5 and August 2, 1968.